Specialty Crop Block Grant Program
FY 2015 Final Performance Reports

COVER PAGE

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Project Title

Season Extension Seminars for Specialty Crop Growers

Project Summary

The Nebraska Department of Agriculture (NDA) hosted four seminars from 2016 – 2018 that addressed season extension practices, such as stationary and moveable high tunnels, cold frames, shade units, and mulches. The seminars were held in areas of the state where there is a strong need and interest in longer growing and harvest seasons. Crop selection, growing techniques, soil nutrition, disease and insect management practices, alternative hybrid varieties, reduced tillage strategies, intensive farming practices, season extension units, and marketing and selling strategies were some of the topics addressed at the seminars. NDA included a piece on financing to provide growers with options they can turn to in an effort to help offset the costs of implementing season extension practices. Each seminar primarily included the following presenters:

1. A chef who performed cooking demonstrations using locally grown produce;
2. A University of Nebraska – Lincoln (UNL) horticulturalist who addressed season extension and plant protection structures and specialty crops to increase farm income;
3. An NDA representative who addressed marketing and selling strategies for specialty crop growers;
4. A representative from the Farm Service Agency who provided affordable financing options; and
5. A retailer who had an interest in sourcing local food from local vendors.

NDA accessed the *Nebraska Farmers Market Online Database*, which consists of approximately 500 Nebraska growers who are actively engaged in the production and selling of fresh fruits and vegetables, to attract seminar participants. Announcements identifying the seminar topics, dates, and locations were sent to growers encouraging them to attend.

Project Approach

Nebraska's fertile Typic Argiustolls soils that expand across Nebraska's 77,358 square miles play a large role in the state's agricultural success. It has enabled fruit and vegetable growers the ability to respond to the rising consumer demand for locally grown produce in recent years. But despite the state's agricultural success, its growing season has its limitations. Growing days range as long as 165 days in the southeast to 120 days in the northwest with killing frosts ranging from October to April and September to May, respectively. Since Nebraska's humid continental and semi-arid climates do not provide fruit and vegetable growers with the luxury of multiple growing seasons within a single calendar year, growers are constantly exploring new avenues with which to extend their seasons to increase crop productivity. In an effort to address this need, this three-year project was designed to conduct four comprehensive seminars to teach specialty crop growers how to implement season extension practices into their farming operations (goal).

The Nebraska Department of Agriculture (NDA) signed an agreement with the University of Nebraska – Lincoln (UNL) to work with a horticulturist on a part-time contractual basis. The horticulturalist assisted NDA with co-hosting the seminars, selecting the seminar topics, curriculum, and presenters. The seminars were held in different areas of the state so as to represent the different topographical landscapes of Nebraska and to allow interested growers an opportunity to attend the seminars that were in close proximity to where they lived. From 2016 – 2018, seminars were held in Lincoln, Kearney, Omaha, and Scottsbluff, Nebraska.

A couple of years ago, NDA provided small, competitive grants to five Nebraska specialty crop growers to implement season extension practices into their farming operations. Tours were held on each farm in an effort to encourage other growers to incorporate similar practices into their own operations. Cumulatively, 138 growers attended the farm tours (benchmark). NDA used this list to determine approximately how many growers were initially interested in season extension practices.

Figure 1

NDA also utilized the *Nebraska Farmers Market Online Database* (http://ne.gov/go/neproduce) to find areas of the state that had the largest concentration of specialty crop growers. This database consists of approximately 500 produce growers who are actively engaged in the production and sales of fresh fruits and vegetables.

Goals and Outcomes Achieved

The goal of this project was to conduct four comprehensive seminars to teach specialty crop growers how to implement season extension practices into their farming operations. It was initially estimated that up to 50 growers, or approximately 10% of Nebraska's produce grower population, would express interest in this project over the course of three years (target). This project far exceeded its goal. Combined, a total of 100 attendees attended the seminars.

First Seminar: February 16, 2016

NDA and UNL determined that the first seminar should be hosted at UNL's East Campus in Lincoln, Nebraska, on February 16, 2016. NDA sent postcards announcing the seminar topics, date, and location of the event to encourage growers to attend (Figure 1). On January 6, 2016, postcards were sent to 509 produce growers in 59 Nebraska counties. On January 5th, this same announcement, which was in the form of an email, was sent to 564 Nebraska fruit and vegetable growers. On January 20th, the UNL Agronomy and Horticulture Department added this announcement to their Facebook page and Twitter feeds. This event was also promoted at

the Nebraska Fruit and Vegetable Growers Association's Annual Meeting in St. Joseph, Missouri, on January 8th. It was estimated that up to 50 growers, or approximately 10% of Nebraska's produce grower population, would express interest in this project (target). This goal came close to meeting its target in the first year as a total of 48 growers RSVP'd for the first seminar and 46 attended. Among the seminar attendees, 39 were growers and 7 were industry representatives.
The seminar included the following presenters:

6. UNL horticulturist who discussed crop selection, growing techniques, soil nutrition, disease and insect management practices, alternative hybrid varieties, intensive farming practices, reduced tillage strategies and various season extension methods and units;

7. Local who chef performed a cooking demonstration using locally grown produce;

8. Season extension outfitter (Hummert International) who showcased their line of season extension products and equipment supply options;

9. Governmental representative from USDA's Farm Service Agency who showcased their affordable financing options that can help offset the costs of season extension units;

10. NDA's Ag Promotion Coordinator talked about marketing and selling strategies for specialty crop growers; and

11. Local retailer (B&R Stores, Inc.), who has a sincere interest in sourcing local food from local vendors, discussed the steps growers should complete in order to sell specialty crops through a retailer. The retailer addressed the challenges and opportunities growers will encounter if selling via this outlet.

Each participant received an educational book that was a comprehensive manual for small-scale farmers raising specialty crops, fruits and vegetables in particular. Seminar pre- and post-surveys were also provided to attendees to determine if the seminar topics, materials, and presentations provided enough information to enable growers to experiment with some type of season extension practice on their farm and if the seminar was beneficial to them (performance measure). Below are the survey questions asked and how they scored on a scale of "Very Low" to "Very High."

	Very Low	Low	Moderate	High	Very High
Learned how specialty crops increase farm income	0	3	16	19	2
Learned about season extension and plant protection structures	0	1	15	17	7
Acquired new recipes using Nebraska produce	7	14	9	5	1
Connected with a produce retailer	2	2	12	15	8
Connected with a season extension outfitter	2	3	11	16	5
Learned about affordable financing options	1	4	1	16	10
Discovered new marketing and selling	2	1	9	12	12

strategies					

The survey also asked the following three questions. Attendees were supposed to mark either "Yes" or "No." Below are the results.

	Yes	No
Did the seminar topics, materials, and presentations provide enough information so you can experiment with some type of season extension practice on your farm?	30	4
Do you anticipate implementing some type of season extension practice on your farm?	33	1
Was the seminar beneficial to you?	32	1

The surveys demonstrated that the seminar topics, materials, and presentations were beneficial and provided enough information to enable growers to experiment with some type of season extension practice on their farm. It was estimated that the post-surveys would show that 10 growers, or 20% of the participants, would implement some type of practice on their farm (target). This target far exceed its expectations in the first year of the project as 33 growers, or 97% of the participants, responded "Yes" to this question (performance measure).

The seminar was recorded and can be found on the *Nebraska Our Best to You* YouTube Channel at http://www.youtube.com/channel/UCUfhUcNUldN4_hf6attsvww.

Second Seminar: February 23, 2017

The second seminar was held in Kearney, Nebraska, which is located in the south central part of the state. NDA announced this event in the form of a postcard that addressed the seminar topics, date, and location (Figure 2). On January 11, NDA mailed this announcement to 578 produce growers. The next day, postcards were sent to 154 growers in 38 counties and it was posted on the Nebraska Fruit and Vegetable Growers Facebook page (https://www.facebook.com/Nebraska-Fruit-and-Vegetable-Growers-Association-254623084768/).

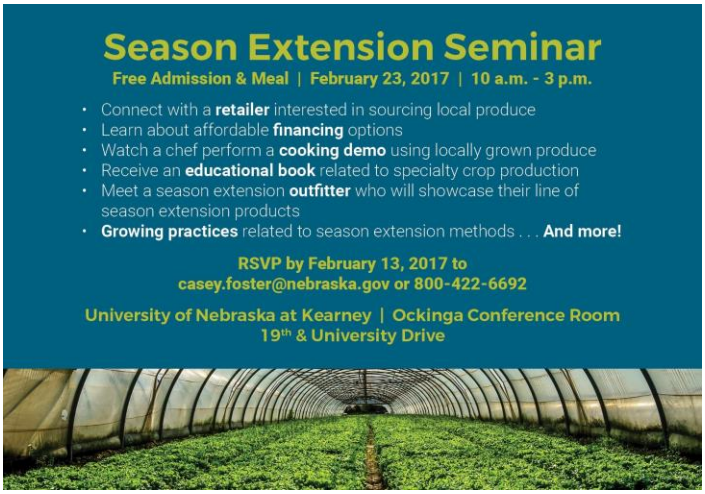

Figure 2

NDA added the event to their social media sites on January 19th, sent the announcement to 71 Nebraska farmer market managers the same day, and contacted the University of Nebraska at Kearney's Agribusiness Club Adviser inviting college agricultural students to attend. NDA sent an additional 42 postcards to growers in 17 counties on January 20th and a press release promoting this event was sent to NDA's media outlets on January 30th (http://www.nda.nebraska.gov/press/january2017/Season-Extension-Seminar.pdf). Approximately 22 growers attended this event, which was held on February 23, 2017.

The seminar included the following presenters:

1. UNL horticulturist discussed crop selection, growing techniques, soil nutrition, disease and insect management practices, alternative hybrid varieties, intensive farming practices, reduced tillage strategies and various season extension methods and units;

2. Two university chefs performed three cooking demonstrations using locally grown produce;

3. Governmental representative from USDA's Farm Service Agency showcased their affordable financing options that can help offset the costs of season extension units;

4. NDA's Ag Promotion Coordinator talked about marketing and selling strategies of specialty crops; and

5. Local retailer (B&R Stores, Inc.), who has a sincere interest in sourcing local food from local vendors, discussed the steps growers should complete in order to sell specialty crops through a retailer. The retailer addressed the challenges and opportunities growers will encounter if selling via this outlet.

Each participant received an educational book that was a comprehensive manual for small-scale farmers raising specialty crops, fruits and vegetables in particular. Seminar pre- and post-surveys were also provided to attendees to determine if the seminar topics, materials, and presentations provided enough information to enable growers to experiment with some type of season extension practice on their farm and if the seminar was beneficial (performance measure). Below are the survey questions asked and how they scored on a scale of "Very Low" to "Very High."

	Very Low	Low	Moderate	High	Very High
Learned how specialty crops increase farm income	0	0	2	18	2
Learned about season extension and plant protection structures	0	3	2	18	5
Acquired new recipes using Nebraska produce	0	0	12	5	5
Connected with a produce retailer	0	1	13	6	2
Connected with a season extension outfitter	3	2	9	7	1
Learned about affordable financing options	0	4	13	10	5
Discovered new marketing and selling strategies	0	1	6	11	4

The survey also asked the following three questions. Attendees were supposed to mark either "Yes" or "No." Below are the results.

	Yes	No
Did the seminar topics, materials, and presentations provide enough information so you can experiment with some type of season extension practice on your farm?	22	0
Do you anticipate implementing some type of season extension practice on	17	5

your farm?		
Was the seminar beneficial to you?	22	0

The surveys demonstrated that the seminar topics, materials, and presentations were beneficial and provided enough information to enable growers to experiment with some type of season extension practice on their farm. It was estimated that the post-surveys would show that 10 growers, or 20% of the participants, would implement some type of practice on their farm (target). This target far exceed its expectations as 17 growers, or 77% of the participants who attended the second seminar, responded "Yes" to this question (performance measure).

Figure 3

Third Seminar: October 20, 2017

The third seminar was held in Omaha, Nebraska, which is located in the eastern central part of the state. NDA announced this event in the form of a postcard that addressed the seminar topics, date, and location (Figure 3).

On September 14th, NDA mailed this announcement to 29 Nebraska produce growers in 46 counties. It was emailed to 69 Nebraska farmers market mangers on October 4th. The next day, an email was sent to 97 Nebraska produce growers who live in the 8 counties closest to the city of Omaha. This announcement was also posted on the Nebraska Fruit and Vegetable Growers Facebook page on September 29th and it reached 627 people (https://www.facebook.com/Nebraska-Fruit-and-Vegetable-Growers-Association-254623084768/?ref=br_tf). NDA contacted the Omaha Agribusiness Club inviting their members to attend. Approximately 20 growers attended this event, which was held on October 20, 2017 at Metropolitan Community College in Omaha, Nebraska.

The seminar included the following presenters:

1. UNL horticulturist discussed crop selection, growing techniques, soil nutrition, disease and insect management practices, alternative hybrid varieties, intensive farming practices, reduced tillage strategies and various season extension methods and units;

2. Two university chefs performed two cooking demonstrations using locally grown produce;

3. Governmental representative from USDA's Farm Service Agency showcased their affordable financing options that can help offset the costs of season extension units;

4. Nebraska retailer (Ideal Market), who has a sincere interest in sourcing local food from local vendors, discussed the steps growers should complete in order to sell specialty crops through a retailer. The retailer addressed the challenges and opportunities growers will encounter if selling via this outlet; and

5. Cooper Farm Tour.

This seminar ended with a farm tour at the Omaha Home for Boys Cooper Farm Urban Ag Education Center. The Urban Agriculture Program at Cooper Farm is an educational partnership connecting the Omaha Home for Boys with UNL Extension and the Nebraska College of Technical Agriculture to offer both informal and formal educational programs including real-life, hands on urban farming. They offer workshops on a variety of topics to help people grow food in and around urban areas and offer classes for certificate and associate degrees in Urban Agriculture from the Nebraska College of Technical Agriculture. A high tunnel was erected in the summer of 2017 and was used to grow produce. The UNL horticulturalist, who worked with NDA on this project, was instrumental in helping build this unit. This gave attendees a first-hand look at a unit and how it could be replicated and scaled to fit their own farming operations.

Each participant received an educational book that was a comprehensive manual for small-scale farmers raising specialty crops, fruits and vegetables in particular. Seminar pre- and post-surveys were also provided to attendees to determine if the seminar topics, materials, and presentations provided enough information to enable growers to experiment with some type of season extension practice on their farm and if the seminar was beneficial (performance measure). Below are the survey questions asked and how they scored on a scale of "Very Low" to "Very High."

	Very Low	Low	Moderate	High	Very High
Learned how specialty crops increase farm income	1	0	4	6	3
Learned about season extension and plant protection structures	1	0	1	8	4
Acquired new recipes using Nebraska produce	1	3	6	4	0
Connected with a produce retailer	3	1	3	4	3
Found a season extension outfitter and gained knowledge of the products they offer	4	2	4	4	0
Learned about affordable financing options	1	1	7	5	0
Visited a farm using a season extension method that could be altered to fit my operation	2	1	6	4	1
Gathered ideas of season extension method(s) that could fit my operation	1	0	3	6	3

The survey also asked the following three questions. Attendees were supposed to mark either "Yes" or "No." Below are the results.

	Yes	No
Did the seminar topics, materials, and presentations provide enough information so you can experiment with some type of season extension practice on your farm?	11	1
Do you anticipate implementing some type of season extension practice on your farm?	9	2
Was the seminar beneficial to you?	12	0

*Some attendees refused to answer some questions on the surveys, which is why a few numbers vary from one row to the next.

Overall, the surveys demonstrated that the seminar topics, materials, and presentations were beneficial and provided enough information to enable growers to experiment with some type of season extension practice on their farm. It was estimated that the post-surveys would show that 10 growers, or 20% of the participants, would implement some type of practice on their farm (target). This target far exceed its expectations as 9 growers, or 64% of the participants who attended the third seminar, responded "Yes" to this question (performance measure).

Fourth Seminar – August 17, 2018

The last seminar was held in Scottsbluff, Nebraska, which is located in the western panhandle of the state. NDA announced this event in the form of a postcard that addressed the seminar topics, date, and location (Figure 4).
On July 13th, NDA mailed this announcement to 67 produce growers who live in western Nebraska. The postcard was sent to the same growers via email on July 24th and was also to the Nebraska Fruit and Vegetable Growers Facebook page https://www.facebook.com/Nebraska-Fruit-and-Vegetable-Growers-Association-254623084768/?ref=br_tf.

On July 30th, UNL Extension sent out a news release through their listserv to promote this event. It reached 145 contacts. A total of 14 growers attended this event, which was held on August 17, 2018 at the University of Nebraska Panhandle Research and Extension Center.

Figure 3

The seminar included the following presenters:

1. UNL horticulturist discussed crop selection, growing techniques, soil nutrition, disease and insect management practices, alternative hybrid varieties, intensive farming practices, reduced tillage strategies and various season extension methods and units;

2. A university chef performed a cooking demonstration using locally grown produce;

3. Governmental representative from USDA's Farm Service Agency showcased their affordable financing options that can help offset the costs of season extension units;

4. Nebraska retailer (Main Street Market), who has a sincere interest in sourcing local food from local vendors, discussed the steps growers should complete in order to

sell specialty crops through a retailer. The retailer addressed the challenges and opportunities growers will encounter if selling via this outlet;

5. NDA's Ag Promotion Coordinator talked about marketing and selling strategies of specialty crops; and

6. Hops production and harvesting demonstration.

The seminar was from 9 a.m. – 2 p.m. and the hops production and harvesting demonstration was from 2:30 – 5:30 p.m. This was intended for people who have an interest in growing hops for a profit making venture. Topics covered during the hops demonstration included growth and development, trellising systems, plant production, cultivar evaluation research, and harvesting and marketing practices. Participants observed the hops research plot and watched a hop cone harvest demonstration using the Hopster 5P cone stripping unit.

Each participant received an educational book that was a comprehensive manual for small-scale farmers raising specialty crops, fruits and vegetables in particular. Seminar pre- and post-surveys were also provided to attendees to determine if the seminar topics, materials, and presentations provided enough information to enable growers to experiment with some type of season extension practice on their farm and if the seminar was beneficial (performance measure). Below are the survey questions asked and how they scored on a scale of "Very Low" to "Very High."

	Very Low	Low	Moderate	High	Very High
Learned how specialty crops increase farm income	0	0	4	8	2
Learned about season extension and plant protection structures	0	1	2	8	3
Acquired new recipes using Nebraska produce	1	2	4	3	4
Connected with a produce retailer	1	0	2	6	5
Learned about affordable financing options	0	0	6	5	3
Gathered ideas of season extension method(s) that could fit my operation	0	1	4	5	4
Increased understanding of hops production and harvesting	1	3	4	1	3

The survey also asked the following three questions. Attendees were supposed to mark either "Yes" or "No." Below are the results.

	Yes	No
Did the seminar topics, materials, and presentations provide enough information so you can experiment with some type of season extension	14	0

practice on your farm?		
Do you anticipate implementing some type of season extension practice on your farm?	11	2
Was the seminar beneficial to you?	14	0

*Some attendees refused to answer some questions on the surveys, which is why a few numbers vary from one row to the next.

Overall, the surveys demonstrated that the seminar topics, materials, and presentations were beneficial and provided enough information to enable growers to experiment with some type of season extension practice on their farm. It was estimated that the post-surveys would show that 10 growers, or 20% of the participants, would implement some type of practice on their farm (target). This target far exceed its expectations as 11 growers, or 78% of the participants who attended the fourth seminar, responded "Yes" to this question (performance measure).

Beneficiaries

Approximately 500 Nebraska produce farms involved in the growing and selling of specialty crops had the potential to be the beneficiaries of this project. Seminars were located in different areas of the state so as to represent the different topographical landscapes of Nebraska and to allow interested growers the opportunity to attend the seminars that were in close proximity to where they lived.

This project will attract a great deal of attention. Existing and beginning specialty crop growers were exposed to how season extension techniques are implemented. The challenges, opportunities, benefits, obstacles, and results were addressed. Popular and affordable season extension practices, financing options, new recipes using local produce, and contact with an outfitter and retailer were also the advantages of attending the seminars. The seminars educated 100 growers and were open to the public and free of charge.

Lessons Learned

After the first seminar, it was apparent from the surveys that growers did not acquire any new recipes that required the use of Nebraska produce. As a result, NDA provided each attendee at the next three seminars with paperback cookbooks that included the use of 80 different recipes requiring the use of specialty crops.

Finding a season extension outfitter to display their line of products at the seminars was very difficult. Despite a captive audience that consisted of growers who wished to extend their season, companies were reluctant to send a representative to showcase what they have to offer. Multiple attempts were made to regional outfitters, but they did not respond.

At the fourth seminar, we decided to add a hop production and harvesting demonstration to the agenda. This activity was well attended by seminar participants and was a great way to showcase a crop that has gained a lot of interest over the past couple of years.

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Project Title

Effect of Plant Population in Great Northern and Pinto Bean Production in Western Nebraska

Project Summary

Nebraska continues to be one of the top dry edible bean producing states in the country. To maintain the market competitiveness of the Nebraska bean industry, agronomic practices must continue to improve. One area of growing interest is the potential for directly harvesting dry beans, in part because direct harvest should reduce soil contamination, thus improving seed quality. One objective of the University of Nebraska Dry Bean Breeding Program is to develop dry bean cultivars with upright plant architecture that are suitable for direct harvest. However, currently there is little information on how plant population affects dry bean yields. Therefore, this project explored the effect of plant population on yield and quality of great northern and pinto beans grown in Nebraska to identify optimal planting densities and row spacing. The short-term objectives were to:

1. Identify the best combinations of plant population and row spacing for great northern and pinto bean cultivars; and

2. Disseminate results through extension meetings, grower-oriented newsletters/ publications, and website postings.

The most important outcome of this project was the identification of optimal plant populations and row spacing for great northern and pinto beans. The interactions between plant population and cultivars were elucidated. Results were disseminated as they became available, beginning with the preliminary trial in 2014 and continuing throughout the study. The results of this study will allow bean growers to consider the latest findings about optimal plant populations for great northern and pinto varieties as they make their planting decisions.

Project Approach

This study was conducted in 2015, 2016, 2017, and 2018 at Scottsbluff, NE (41◦53.6′ N, 103◦40.7′ W, 1200 m elevation). The soil in this area of the state has a very fine, sandy loam and coarsely mixed soil.

Two great northern, ‘Marquis’ (III) and ‘Draco’ (II), and two pinto cultivars, Montrose (III) and Sinaloa (II) were planted in separate experiments at two row spacing (30 and 15 inches) and four plant densities. Target population for the 30 inch row spacing was 45,000, 80,000, 100,000, and 120,000 plants acre^{-1}. Target population for the 15 row spacing was 80,000, 100,000, 120,000, and 150,000 plants acre^{-1}. Four and seven rows were planted for the 30 and 15 inch row spacing experiments, respectively.

For the 22 row spacing, three great northern, ‘Sinaloa’, ‘Montrose’, and ‘Poncho (III), and three pinto cultivars, Marquis, Draco, and Aries (II) were planted in separate experiments at four plant densities (45,000, 80,000, 100,000, and 120,000 plants acre^{-1}). Four rows were planted for the 22 inch row spacing experiments.

Data recorded included stand counts, days to flowering (days from sowing to 50% of the plants has a least one open flower), days to physiological maturity (days from sowing to 90% of plants with dry pods ready to harvest), seed yield (plants/acre), and 100-seed weight (g).

Four different experiments were planted in 2015, 2016, 2016, and 2018. The factorial of plant populations (4) and cultivars (2, one upright and one prostrate growth habit) were arranged in a randomized block design and replicated four times.

The statistical SAS package was used to analyze the data. Cultivars and plant populations were considered as fixed factors, and years were random.

Goals and Outcomes Achieved

For both great northern cultivars, Draco and Marquis, at 22-inch row spacing, yield at 45,000 and 80,000 plants/acre was significantly lower than at 100,000 and 120,000 plants/acre. For both pinto cultivars, Sinaloa and Montrose, at 22-row spacing, yield of both cultivars continued to increase as plant population increased and was greatest at 120,000 plants/acre. For both market classes, great northern and pinto beans, at 30-inch row spacing, yield was similar among the 4 plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre, respectively) for both cultivars. For the pinto beans at 15-inch row spacing, yield did not differ across plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre). Yield of great northern Draco declined significantly when the plant population was increased from 80,000 to 150,000 plants/acre. Yield of great northern Marquis was significantly lower at 80,000 plants/acre (2,831 lbs/acre) than at plant populations of 120,000 and 150,000 plants/acre.

For both market classes, great northern and pinto beans, at 22-inch row spacing, seed size was significantly reduced at a plant population of 120,000 plants/acre compared to seed size at 45,000 plants/acre. For both great northern cultivars, Draco and Marquis, at 15-row spacing, seed size was slightly reduced at a plant population of 150,000 plants/acre. For both pinto bean cultivars, Montrose and Sinaloa, seed size was slightly reduced at a plant population of 100,000 and 150,000 plants/acre.

For both market classes, great northern and pinto beans, at 22-inch row spacing, plants reached physiological maturity earlier at plant populations of 100,000 and 1200,000 plants/acre than at 45,000 plants/acre. For both market classes, great northern and pinto beans, at 30-inch row spacing, plants reached physiological maturity significantly later at 45,000 plants/acre than at 80,000, 100,000, and 120,000 plants/acre. For the pinto beans at 15-inch row spacing, days to physiological maturity at harvest did not differ across plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre). Great northern Draco reached physiological maturity significantly later at a plant population of 80,000 plants/acre than at 150,000 plants/acre.

Beneficiaries

Below are the plans for continuing the project (sustainability; capacity building) and/or disseminating the project results.

A poster presentation entitled “Effect of Plant Population in Great Northern and Pinto Bean Production in Western Nebraska” was presented at the Bean Improvement Cooperative (BIC) meeting at Ontario, Canada from November 2 – 3, 2015 and at the Nebraska Dry Bean Growers

Association Bean Day\' on February 7, 2017 at the Gering Civic Center. About 120 dry bean growers attended the meeting.

An oral presentation on the project was presented during the Nebraska Dry Bean Growers Association Bean Day on January 12, 2016 at the Gering Civic Center. Approximately 120 dry bean growers attended the meeting.

A brief report of the current studies were presented during the following events:

1. Nebraska Dry Bean Growers Association day on August 16, 2016 and approximately 120 dry bean growers attended.

2. Nebraska Dry Bean Growers Association day on August 22, 2017. Approximately 150 dry bean growers attended.

3. Nebraska Dry Bean Growers Association day on February 13, 2018. About 180 dry bean growers attended.

4. Nebraska Dry Bean Growers Association field day on August 29, 2018. About 120 dry bean growers attended.

5. Final results will be presented during the Nebraska Dry Bean Growers Association day

Results were also published in the *Bean Bag*, which is a newsletter published by the Nebraska Dry Bean Growers Association (vol. 33(4): 10 & 21 and vol. 35 (1): 4, 7, &8.) The information provided is this document is designed to keep dry bean growers up-to-date on the latest research, pertinent political information, and other changes and developments that affect the dry bean industry. The *Bean Bag* reaches approximately 1,700 growers.

Lessons Learned

NE21 (22-inch row spacing great northern beans)

Since 2015, Marquis (3037 lbs/acre) had significant higher yield than Draco (3,037 lbs/acre). For both cultivars, yield at 45,000 and 80,000 plants/acre was significantly lower than at 100,000 and 120,000 plants/acre. Draco (32.1 g/100 seeds) had significantly larger seed size than Marquis (30.9 g/100 seeds). For both cultivars, seed size was significantly reduced at a plant population of 120,000 plants/acre (31.1 g/100 seeds) compared to seed size at 45,000 plants/acre (31.9 g/100 seeds). Marquis (90.8 days) reached physiological maturity significantly earlier than Draco (91.5 days). Both cultivars matured one day earlier at plant populations of 100,000 and 1200,000 plants/acre than at 45,000 plants/acre.

NE22 (22-inch row spacing, pinto beans)

Since 2015, yield differed significantly by environment, cultivar, and plant population across seven environments (P = 0.05, 0.05, and 0.06, respectively). Sinaloa (3,266 lbs/acre) had significantly higher yield than Montrose (2937 lbs/acre). Yield of both cultivars continued to increase as plant population increased and was greatest at 120,000 plants/acre. For both cultivars, yield at 120,000 plants/acre (3188 lbs/acre) was significantly greater than at 45,000 plants/acre (2984 lbs/acre) and was similar to yield at 80,000 plants/acre (3,140 lbs/acre).

Sinaloa (34.5 g/100 seeds) had significantly smaller seed size than Montrose (32.0 g/100 seeds). Seed size was significantly reduced at a plant population of 120,000 plants/acre (33.0 g/100 seeds) compared to seed size at 45,000 plants/acre (33.7 g/100 seeds). Montrose (86.9 days) reached physiological maturity significantly earlier than Sinaloa (89.3 days). Both cultivars matured one day earlier at plant populations of 100,000 and 1200,000 plants/acre than at 45,000 plants/acre.

NE23 (30-inch row spacing, great northern beans)

Since 2015, yield of Draco (2,778 lbs/acre) did not differ from that of Marquis (2,829 plants/acre) across years. Yield (2,741, 2,725, 2,872, and 2,876 lbs/acre) was similar among the 4 plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre, respectively) for both cultivars. For both cultivars, yield was significantly lower in 2016 (2,253 plants/acre) than in 2017 (3,715 plants/acre). Marquis (30.8 g/100 seeds) had significantly smaller seed size than Draco (33.2 g/100 seeds). Seed size was significant larger at 45,000 plants/acre (32.6 g/100 seeds) than at 120,000 plants/acre (31.8 g/100 seeds). Marquis (93.6 days) reached physiological maturity significantly earlier than Draco (93.8 days). Plants reached physiological maturity significantly later at 45,000 plants/acre (93.6 days) than at 80,000, 100,000, and 120,000 plants/acre.

NE24 (30-inch row spacing, pinto beans)

Yield of Montrose (3,104 lbs/acre) was significantly higher than yield of Sinaloa (2,807 lbs/acre). Yield did not differ across plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre). Montrose (35.5 g/100 seeds) had significant larger seed size than Sinaloa (32.5 g/100 seeds). Seed size also varied among plant populations with smaller seed size at 45,000 plants/acre (34.6 g/100 seeds) than at 100,000 and 120,000 plants/acre (33.5 and 33.7 g/100 seeds, respectively). Seeds size was also significantly smaller at 80,000 than at 100,000 plants/acre (34.1 to 33.5 g/100 seeds, respectively). Sinaloa (90 days) reached physiological maturity significantly later than Montrose (88.3 days). For both pinto cultivars, days to physiological maturity at harvest was significantly later at 45,000 plants/acre (90.0 days) than at 80,000, 100,000, and 120,000 plants/acre (88.6, 88.7, and 89.2 days, respectively).

NE26 (15-inch row spacing, great northern beans)

Draco (3,188 lbs/acre) had a slight higher yield than Marquis (3,067 lbs/acre) across years. Yield of Draco declined significantly when the plant population was increased from 80,000 to 150,000 plants/acre (3,294 and 3,003 lbs/acre, respectively). Yield of Marquis was significantly lower at 80,000 plants/acre (2,831 lbs/acre) than at plant populations of 120,000 and 150,000 plants/acre (3,201 and 3,239 lbs/acre, respectively). Draco (33.6 g/100 seeds) had significantly larger seeds than Marquis (31.1 g/100 seeds). For both Draco and Marquis, seed size was slightly reduced at a plant population of 150,000 plants/acre (33.4 and 30.6 g/100 seeds, respectively). Days to physiological maturity at harvest was the same for both great northern cultivars, Marquis and Draco. However, Draco reached physiological maturity significantly later at a plant population of 80,000 plants/acre (95.1 days) than at 150,000 plants/acre (94.1 days).

NE27 (15-inch row spacing, pinto beans)

Yield of Sinaloa (3,075 lbs/acre) was slight higher than yield of Montrose (3,024 lbs/acre). Yield did not differ across plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre).
Montrose (35.3 g/100 seeds) had significant larger seed size than Sinaloa (32.4 g/100 seeds). For both Montrose and Sinaloa, seed size was slightly reduced at a plant population of 100,000

and 150,000 plants/acre (33.4 and 33.3 g/100 seeds, respectively). Sinaloa (92.3 days) reached physiological maturity significantly later than Montrose (89.6 days). Days to physiological maturity at harvest did not differ across plant populations (45,000, 80,000, 100,000, and 120,000 plants/acre).

Contact Information

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Additional Information

Table 1. Great northern beans planted at 22 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	6107 (Draco)	45000	3696	47	98	32.0
2	6107 (Draco)	80000	3392	47	98	32.7
3	6107 (Draco)	100000	4684	46	97	35.7
4	6107 (Draco)	120000	4071	46	97	32.4
5	Marquis	45000	3816	45	96	31.7
6	Marquis	80000	4092	45	95	31.8
7	Marquis	100000	4278	44	92	32.1
8	Marquis	120000	4041	45	95	31.4
	GRAND MEAN		4009	45	96	32.5
	LSD (0.05)		738	1	4	3.3
	CV %		8.9	1.3	1.9	4.9

Table 2. Great northern beans planted at 22 inches row spacing and four plant populations at Scottsbluff, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	6107 (Draco)	45000	3123	47	92	32.4
2	6107 (Draco)	80000	3291	46	91	32.6
3	6107 (Draco)	100000	2887	46	90	31.9
4	6107 (Draco)	120000	3134	46	90	30.7
5	Marquis	45000	2978	45	91	30.5
6	Marquis	80000	3031	45	88	30.0

7	Marquis	100000	3054	46	88	30.9
8	Marquis	120000	2941	45	89	29.9
	GRAND MEAN		3055	46	90	31.1
	LSD (0.05)		529	1	3	2.0
	CV %		8.4	1.0	1.4	3.2

Table 3. Great northern beans planted at 22 inches row spacing and four plant populations at Mitchell and Scottsbluff, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	6107 (Draco)	45000	3411	47	95	32.2
2	6107 (Draco)	80000	3343	47	94	32.7
3	6107 (Draco)	100000	3788	46	93	33.8
4	6107 (Draco)	120000	3604	46	94	31.5
5	Marquis	45000	3399	45	93	31.1
6	Marquis	80000	3563	45	92	30.9
7	Marquis	100000	3668	45	90	31.5
8	Marquis	120000	3493	45	92	30.6
	GRAND MEAN		3534	46	93	31.8
	LSD (0.05)		583	1	1	1.5
	CV %		12.5	1.6	2.4	5.9

Table 4. Pinto beans planted at 22 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	Sinaloa	45000	4126	46	95	32.7
2	Sinaloa	80000	4168	46	94	32.5
3	Sinaloa	100000	4065	45	94	31.9
4	Sinaloa	120000	4370	46	93	33.6
5	Montrose	45000	3847	46	90	36.7
6	Montrose	80000	3438	46	92	35.5
7	Montrose	100000	3509	46	91	36.0
8	Montrose	120000	3955	46	91	37.3
	GRAND MEAN		3935	46	92	34.5
	LSD (0.05)		868	1	2	3.9
	CV %		10.7	1.5	1.3	5.4

Table 5. Pinto beans planted at 22 inches row spacing and four plant populations at Scottsbluff, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	Sinaloa	45000	3479	46	90	31.6
2	Sinaloa	80000	3191	46	89	30.3
3	Sinaloa	100000	3681	45	89	**32.6**
4	Sinaloa	120000	3611	46	89	30.8
5	Montrose	45000	3130	47	88	35.8
6	Montrose	80000	2979	46	88	36.6
7	Montrose	100000	2865	47	88	36.2
8	Montrose	120000	2963	47	88	37.3
	GRAND MEAN		3237	46	88	33.9
	LSD (0.05)		519	1	3	2.4
	CV %		7.8	1.2	1.6	3.5

Table 6. Pinto beans planted at 22 inches row spacing and four plant populations at Mitchell and Scottsbluff, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	Sinaloa	45000	3804	46	92	32.2
2	Sinaloa	80000	3682	46	92	31.4
3	Sinaloa	100000	3875	45	92	32.3
4	Sinaloa	120000	3992	46	91	32.2
5	Montrose	45000	3490	47	89	36.2
6	Montrose	80000	3210	46	90	36.0
7	Montrose	100000	3189	46	90	36.1
8	Montrose	120000	3461	46	89	37.3
	GRAND MEAN		3588	46	90	34.2
	LSD (0.05)		257	1	1	1.6
	CV %		13.7	1.9	2.0	6.5

Table 7. Great northern beans planted at 30 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent No.	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
		No. plants	lbs/A	days	days	gr
1	6107 (Draco)	45000	3874	48	96	36.2
2	6107 (Draco)	80000	3327	49	96	34.2
3	6107 (Draco)	100000	3720	47	95	36.6
4	6107 (Draco)	120000	3776	48	95	35.6
5	Marquis	45000	3839	44	90	33.2
6	Marquis	80000	3631	44	91	32.7
7	Marquis	100000	3766	44	91	32.6
8	Marquis	120000	3792	44	91	32.9
	GRAND MEAN		3716	46	93	34.2
	LSD (0.05)		527	2	1	2.2
	CV %		6.9	1.9	0.8	3.1

Table 8. Pinto beans planted at 30 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	Sinaloa	45000	3616	48	91	34.6
2	Sinaloa	80000	3540	48	90	34.1
3	Sinaloa	100000	3294	48	90	33.6
4	Sinaloa	120000	3653	48	90	34.7
5	Montrose	45000	3916	44	89	37.5
6	Montrose	80000	3864	44	89	36.6
7	Montrose	100000	4113	44	89	36.7
8	Montrose	120000	4029	44	89	37.1
	GRAND MEAN		3753	46	90	35.6
	LSD (0.05)		596	1	1	2.0
	CV %		7.7	0.7	0.8	2.7

Table 9. Great northern beans planted at 15 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight

no		No. plants	lbs/A	days	days	gr
1	6107 (Draco)	80000	3255	50	97	34.2
2	6107 (Draco)	100000	3423	49	97	33.4
3	6107 (Draco)	120000	3732	49	97	34.6
4	6107 (Draco)	150000	3077	49	97	32.9
5	Marquis	80000	2868	45	95	32.0
6	Marquis	100000	3380	43	95	32.2
7	Marquis	120000	3405	44	96	32.3
8	Marquis	150000	3510	44	96	32.4
	GRAND MEAN		3331	47	96	33.0
	LSD (0.05)		567	1	2	1.8
	CV %		8.3	1.2	0.9	2.7

Table 10. Pinto beans planted at 15 inches row spacing and four plant populations at Mitchell, NE during 2017.

Ent	PEDIGREE	Plant population	Yield	Flowering	Maturity	100-SeedWeight
no		No. plants	lbs/A	days	days	gr
1	Sinaloa	80000	3421	48	92	32.9
2	Sinaloa	100000	3348	48	93	32.1
3	Sinaloa	120000	3907	48	94	33.9
4	Sinaloa	150000	3640	48	92	33.2
5	Montrose	80000	4043	45	90	36.8
6	Montrose	100000	4258	45	89	35.3
7	Montrose	120000	3456	45	89	36.5
8	Montrose	150000	3862	45	90	35.4
	GRAND MEAN		3742	47	91	34.5
	LSD (0.05)		488	1	3	2.0
	CV %		6.3	0.9	1.4	2.8

Project Title

Hops Cultivar and Production Evaluation for Nebraska

Project Summary

The craft brewing industry contributed more than $34 billion to the U.S. economy in 2012 with an economic impact of $194 million to Nebraska alone. Craft brewers make up over 7.8% of the overall beer market. Domestic sales increased by 17.2% and exports increased by 49% between 2012 and 2013. There are currently 22 commercial microbreweries in Nebraska as identified by the Nebraska Craft Brewers Guild and a number of emerging or hobby brewers. The Hop Growers of America 2014 Statistical Report indicated that only 12 acres of hops was harvested in Nebraska that year.

The majority of U.S. grown hops (98%) is from Washington, Oregon and Idaho having a combined 38,011 acres harvested. The introduction of new high value crops to Nebraska specialty crop growers having a research grounded foundation directly impacts farm income and provides more employment opportunities for rural NE. The purpose of this project was to explore the potential for Nebraska to have extensive commercial hop production through evaluation of eight industry proven hop cultivars grown in Nebraska's unique geographical and environmental conditions. Observations and research findings are to be used for development of extension outreach products and direction of future research in hop production in NE.

Project Approach

This three-year project was to conduct a hops (*Humulus lupulus*) cultivar trial at four locations with varying soil and environmental conditions to identify the relative success of commercial production of this emerging crop for specialty crop growers. A fifth planting was established on the University of Nebraska-Lincoln (UNL) campus for monitoring of cultural treatments and activity timing. This project provided foundational data useful for decision making by growers considering production of hops in Nebraska and by existing growers looking to expand their production.

Project Objectives

- Identify eight hop cultivars that have attributes desired by craft brewers and cultural requirements conducive to production in NE to study for this project and find four cooperator sites;
- measure speed of establishment from planting to first productive harvest;
- evaluate the winter hardiness of individual varieties in varying soil/environmental conditions in NE;
- complete cultivar qualitative analysis through alpha- and beta- acid testing in comparison to those levels expected by individual cultivar benchmarks set forth by industry standards;
- measure cultivar yields and annual comparisons; and
- collect observational growth/handling information useful for outreach products.

Accomplishments Year 1 (September 30, 2015-September 29, 2016)

- Researchers determined that 8 cultivars should be evaluated, better evaluating both bittering and aroma hop characteristics and provide a larger footprint of trial sites for improved microclimate in block planting design

- Cultivars selected were: Columbia, Centennial, Chinook, Crystal, Perle, Willamette, Cluster and Zeus. *Healthy stock of Cascade unavailable and substituted with Columbia.*
- Four trial sites identified:
  - Lancaster County, NE
  - Madison County, NE
  - Clay County, NE
  - Scotts Bluff County, NE
- Trellis and irrigation materials ordered, delivered, and installed
- Soil preparation and modification as determined by testing
- Rooted hop plants sourced and planted May 2016

Impacts Year 1

- Two seminars and field tours were conducted
- Ninety-seven attended the first seminar on June 20, 106 with 84 that completed the follow-up survey indicating a 36% in gain of knowledge. The survey identified 21 would try growing hops in the next year, 31 said they were going to investigate hops production as a commercial venture as a result of the seminar, and 9 said they are presently in the planning/installation of a new hops yard.
- The second seminar and field tour was conducted on September 12, 2016 at the Panhandle Research and Extension Center in Scottsbluff, NE. There were 28 in attendance. Results of the pre- and post-knowledge quizzes and survey indicated a 40% increase in knowledge about hops. Six individuals indicated they would try growing hops in the next year as a result of the seminar, 6 were interested in investigating hops production as a commercial profit venture and 2 were strongly considering development of a hops yard as a profit venture in the next year.

Accomplishments Year 2 (September 30, 2016 – September 29, 2017)

- Plant establishment was 100% at the Valparaiso, Sutton, and PHREC sites and 95% at the Norfolk cooperator site. Plant health and survival was directly related to the care given, specifically ensuring irrigation was properly place over the root zone of the plants. Plants were replaced at the Norfolk site to provide a complete planting for all replications.
- Developed cultivation protocols through literature interpretation in relation to NE environmental conditions. The following production plan was utilized for the 12' modified hop trellis system used in this project;
  - March 30- Spring cleanup cut-back
  - May 1- 50# N/acre as Urea
  - May 15- Timed cut-back
  - June 1-14- Training period
  - June 2- 75# N/acre as Urea
  - June 15- 75# N/acre as Urea
  - August/September- Harvest identified as 20% accumulated dry weight in cone

Results Year 2

The hop plants are in their second year of growth, the first year for harvestable cones. The yield target (quantitative evaluation) for this first harvest is at least half of that for mature plants, which typically occurs in year three. Alpha and beta acid measurements were additionally made at cone harvest to evaluate hop quality.

Hop cone harvest was determined by dry weight sampling and complete when the dry weight accumulation was approximately 23% for each cultivar. A subsample was then dried to 10% and

sent to *Karr Laboratories, Inc.* (Kalamazoo, MI) for qualitative analysis testing. The following summarizes the quantitative results for year 1 harvest;

2017 Hop Quantity and Quality Summary
[t] *indicates cultivar target from literature using standard trellis system*

Cultivar	Location	Harvest Weight Per Plant	Alpha Acid Alpha	Beta Acid Beta
Columbia		1.5# [t]	8.80% [t]	4% [t]
	Norfolk	0.28	10.8	3.3
	PHREC	0.89	8.41	2.81
	Sutton	0.48	11.2	3.26
	Valparaiso	0.2	10.4	2.99
Centennial		1.5# [t]	9.5 - 11.5% [t]	3.5 - 4.5% [t]
	Norfolk	0.25	13.7	3.93
	PHREC	0.6	4.93	4.33
	Sutton	0.35	9.01	2.46
	Valparaiso	0.3	10.4	2.63
Chinook		1.5 - 2.0# [t]	12 - 14% [t]	3 - 4% [t]
	Norfolk	0.81	9.75	2.91
	PHREC	1.7	8.69	2.2
	Sutton	1.3	6.67	1.44
	Valparaiso	1.1	12	3.06
Crystal		1.8 - 2.2# [t]	2.8 - 4.4% [t]	5.8 - 7% [t]
	Norfolk	0.43	3.46	4.79
	PHREC	1.2	5.94	7.84
	Sutton	1	4.21	4.51
	Valparaiso	0.38	7.1	7.22
Perle		1.0 - 1.4# [t]	6 - 10% [t]	3 - 5% [t]
	Norfolk	0.04	4.84	5.26
	PHREC	0.4	6.16	2.69
	Sutton	0.09	4.61	1.96
	Valparaiso	0.06	8.25	3.67
Willamette		1.2 - 1.5# [t]	4 - 6% [t]	3 - 4% [t]
	Norfolk	0.15	5.95	4.47
	PHREC	0.46	2.33	1.53
	Sutton	0.13	4.3	2.99
	Valparaiso	0.14	4.52	3.11
Cluster		1.4 - 1.9# [t]	5.5 - 9% [t]	4 - 6% [t]
	Norfolk	0.86	7.77	5.27
	PHREC	2.1	5.83	4.08
	Sutton	1.4	7.33	4.82
	Valparaiso	0.9	9.51	5.82

Zeus (CTZ)		2.4 - 3.0# [t]	13 - 17.5% [t]	4.5 - 6.5% [t]
	Norfolk	1.8	18.7	5.18
	PHREC	2.8	17.1	4.83
	Sutton	1.6	16.7	4.38
	Valparaiso	1.8	20.3	5.08

Impacts Year 2
Three workshops were presented this year:

June 8, 2017- *Introductory Hop Workshop* at the University of Nebraska-Lincoln (UNL) in the East Campus Plant Science Hall. This program provided general information on hop growth and the commercial aspects of hop production.

Impacts- 46 individuals in attendance (3 industry members, 12 specialty crop farmers, 5 research/extension/education members, 26 others with interest).

A post-survey indicated:
- 81% of attendees' improved their basic knowledge of hop production
- 97% of attendees' understanding of key components of hop production increased
- 66% of attendees' strongly believe they have the skills to grow hops after attending the workshop
- 28% of attendees' intention to grow hops increased after attending the workshop
- 16% of attendees' intention went down
- 69% of attendees strongly believe hops have the potential to be a value-added agricultural opportunity for Nebraska farmers

July 19, 2017- *Hop Production Workshop and Tour* at the Pan Handle Research and Extension Center (PHREC) in Scottsbluff, NE. This program provided information on hops trellising, cultivation requirements, and determination of harvest.

Impacts- 17 individuals attended (2 media, 3 research/extension/education, 8 specialty crop farmers, 4 interested individuals).

In a post-survey:
- 92% indicated they strongly agreed their goals for attending the workshop were accomplished
- 100% indicated that the program greatly increased their knowledge on hop production
- 67% said that as a result of this program they plan to pursue or expand their own hop production operation.

August 25, 2017- *Hop harvest determination and demonstration* at the UNL east campus hop tall trellis demonstration site. This program allowed participants to explore the tall trellis hop yard on campus and engage with commercial growers and researchers on how to determine harvest/maturity of hop cones and demonstrated the removal of mature cones using a small farm sized hop harvester.

Impacts- 32 individuals were in attendance of which 23 post-surveys were returned. 17% of those attending were presently growing hops commercially, 39% were growing hops for

personal use, 30% were not growing hops but intend to and 14% responded as “other”. Two individuals were University Extension personnel from Missouri, two were UNL researchers and 1 representative from the State of Nebraska Department of Agriculture- Agriculture Promotion program.

In a post-survey:

- 96% of the participants indicated their goals of attending the workshop were met
- 92% indicated that they greatly improved their knowledge of hops harvesting on a small scale as a result of the workshop
- 48% felt that as a result of the workshop, they fully have the necessary skills to know when and how to harvest hops
- 52% somewhat felt they have the necessary skills to know when and how to harvest hops.

Accomplishments Year 3 (September 30, 2017-September 29, 2018)

The hop plants are in their third year of growth, the second year for harvestable cones. The yield target (quantitative evaluation) for this first harvest is expected to be nearing that for mature plants, which typically occurs in harvest year three. Alpha and beta acid measurements were additionally made at cone harvest to evaluate hop quality.

- Spring warm up of soils resulted in later emergence of plant complicating cultivation protocol. The decision was made to not do an early cutback of spring hop plant growth and to do only the timed cutback for growing the hop bines to top wire of trellis system. In general, the late cutback delayed many in regrowth, reduced bine length, and prevented some from being productive.
- This was generally an excessively wet year resulting in increased disease pressure at all locations except for the SB location (Scottsbluff) which is near the Colorado/Wyoming and in very sandy loam soils.
- Many of the cultivars were ready to harvest at the same time and the travel distances were such that the researchers failed to hit targets as we liked. This resulted in higher dry weight content then our target
- Cultivars that were consistent were; Centennial at all sites, Chinook at all sites, Willamette all except TT (Lincoln), and Zeus except for NOR (Norfolk)
- Perle has not been a good plant at all sites and extremely unpredictable. The alpha and beta acid contents are highly variable for all years tested and irregular between sites.

Hop cone harvest was determined by dry weight sampling and complete when the dry weight accumulation was approximately 20% for each cultivar. A subsample was then dried to 10% and sent to *Alliance Analytical Laboratories, Inc.* (Coopersville, MI) for qualitative analysis testing. The following summarizes the quantitative and comparative results for year 1 and 2 harvests;

Hop Quantity and Quality Summary

Cultivar	Location	Harvest Weight Dry Wt. Plant		Alpha Acid Alpha		Beta Acid Beta	
Columbia		1.5# [t]		8.80% [t]		4% [t]	
		2017	2018	2017	2018	2017	2018
	Norfolk	0.28	1.15	10.8	25.7	3.3	7.09

	PHREC	0.89	0.90	8.41	11.8	2.81	3.92
	Sutton	0.48	0.18	11.2	16.5	3.26	4.54
	Valparaiso	0.2	0	10.4	0	2.99	0
	Lincoln TT	0.36	0.37	9.44	13.5	2.87	3.67
Centennial		1.5# [t]		9.5 - 11.5% [t]		3.5 - 4.5% [t]	
	Norfolk	0.25	0.29	13.7	11.3	3.93	4.39
	PHREC	0.6	0.53	4.93	12.7	4.33	4.34
	Sutton	0.35	0.09	9.01	12.0	2.46	4.14
	Valparaiso	0.3	0.07	10.4	11.9	2.63	4.33
	Lincoln TT	0.33	0.23	3.57	11.1	5.75	4.74
Chinook		1.5 - 2.0# [t]		12 - 14% [t]		3 - 4% [t]	
	Norfolk	0.81	1.50	9.75	13.3	2.91	3.87
	PHREC	1.7	1.02	8.69	10.7	2.2	3.64
	Sutton	1.3	0.51	6.67	13.1	1.44	3.62
	Valparaiso	1.1	0.63	12	13.9	3.06	3.29
	Lincoln TT	1.03	1.29	10.2	12.2	2.03	3.77
Crystal		1.8 - 2.2# [t]		2.8 - 4.4% [t]		5.8 - 7% [t]	
	Norfolk	0.43	0.21	3.46	6.06	4.79	7.57
	PHREC	1.2	0.98	5.94	9.32	7.84	7.54
	Sutton	1	0.37	4.21	8.28	4.51	7.96
	Valparaiso	0.38	0	7.1	0	7.22	0
	Lincoln TT	0.63	0.74	2.94	6.04	5.63	8.56
Perle		1.0 - 1.4# [t]		6 - 10% [t]		3 - 5% [t]	
	Norfolk	0.04	min	4.84	8.79	5.26	4.90
	PHREC	0.4	0.27	6.16	12.0	2.69	4.77
	Sutton	0.09	min	4.61	12.9	1.96	4.14
	Valparaiso	0.06	0	8.25	0	3.67	0
	Lincoln TT	0.26	min	3.63	5.62	2.47	3.76
Willamette		1.2 - 1.5# [t]		4 - 6% [t]		3 - 4% [t]	
	Norfolk	0.15	0.12	5.95	4.10	4.47	4.76
	PHREC	0.46	0.47	2.33	6.18	1.53	4.63
	Sutton	0.13	0.06	4.3	4.16	2.99	3.24
	Valparaiso	0.14	min	4.52	3.76	3.11	4.25
	Lincoln TT	0.18	0.15	2.16	2.72	2.40	2.67
Cluster		1.4 - 1.9# [t]		5.5 - 9% [t]		4 - 6% [t]	
	Norfolk	0.86	0.41	7.77	10.2	5.27	6.29
	PHREC	2.1	1.67	5.83	10.6	4.08	6.31
	Sutton	1.4	0.17	7.33	11.7	4.82	6.39
	Valparaiso	0.9	0.83	9.51	8.22	5.82	5.57
	Lincoln TT	1.83	1.00	3.69	12.2	5.28	6.95
Zeus (CTZ)		2.4 - 3.0# [t]		13 - 17.5% [t]		4.5 - 6.5% [t]	
	Norfolk	1.8	1.44	18.7	25.7	5.18	7.09

PHREC	2.8	1.10	17.1	16.3	4.83	7.24
Sutton	1.6	0.90	16.7	17.50	4.38	6.29
Valparaiso	1.8	0.44	20.3	19.0	5.08	6.05
Lincoln TT	2.9	1.22	19.0	19.0	4.36	6.58

[t] *indicates cultivar target from literature using standard trellis system*

Year 3 Impacts

Four educational outreach programs were presented this year:

June 8, 2018- *Introductory Hop Workshop and Research Update* at the University of Nebraska-Lincoln (UNL) in the East Campus Plant Science Hall. This program provided general information on hop growth, the commercial aspects of hop production, and a walking tour of the on campus hop research planting. There were 43 in attendance in which a post-survey indicated:

- 67% of attendees' improved their basic knowledge of hop production
- 45% of attendees' strongly believe they have the skills to grow hops after attending the workshop
- 28% of attendees' intention to grow hops increased after attending the workshop
- 74% of attendees' indicated the educational content was worthwhile

June 29, 2018- *Hop Production Field Tour* at the Pan Handle Research and Extension Center (PHREC) in Scottsbluff, NE. 14 individuals attended (1 media, 3 research/extension/education, 6 specialty crop farmers, 4 interested individuals).

August 17, 2018- *Hop Harvest Demonstration* at the Pan Handle Research and Extension Center (PHREC) in Scottsbluff, NE.

- Impacts: There were 18 in attendance representing 15 Nebraska, 3 South Dakota, and 1 Wyoming specialty crop farmers. 100% of the participants indicated the information was valuable, 57% indicated they were able to learn something new from the event, and 21% indicated the information was valuable to their own farming operation.

August 24, 2018- *Determination of hops maturity and hop harvest demonstration* at the University of Nebraska-Lincoln (UNL) East Campus hop research planting.

- Impacts: There were 46 in attendance representing 41 Nebraska, 3 Kansas, and 2 Missouri specialty crop farmers and researchers. 100% of the participants indicated the information was timely, 87% indicated they were able to learn something new from the event, and 38% indicated the information was valuable to their own farming operation.

Additional Outreach

September 21-22, 2018- *Colorado and Nebraska/USDA-FAS Foreign Ag Attaché Tour*. PHREC Hop research tour stop. 29 international guests representing China, Australia, France, Thailand, Ireland, Canada, Lithuania, Germany Philippines, Belgium, Kenya, Brazil, Malaysia, Argentina, South Korea, Spain, Mexico, Bangladesh, Switzerland, UK, Madagascar, and South Africa. In addition, there were 3 USDA representatives and 8 Nebraska and Colorado delegates.

UNL Nebraska Hops Webpage- Since the beginning of this project on September 30, 2015, there have been 61,425 page views of which 48,302 were unique views, having an average viewing time of 1:45 for all views.

Goals and Outcomes Achieved

The original grant request focused specifically on the following two key goals

Goal 1:Increase in knowledge about growing hops in Nebraska

- *Performance measure*- Percentage of increase in knowledge as measured through pre- and post-tests of information given at farm tours and other presentations
- *Benchmark*- Results of pre-test at farm tours and other presentations
- *Target*- A mean increase in specific knowledge by at least 25%

Goal 1 Measured Outcomes

- Nine formal outreach programs were given during the three-year project, reaching more than 341 individuals through direct interaction and an identified 82.5% increase in knowledge measured through returned post-event surveys. This exceeds the target of an increase in knowledge of 25%.

Goal 2:Increase the number of hops growers and acreage produced

- *Performance measure*- Number of existing growers who indicate expanding their hops acreage and number of new farmers expressing an interest in beginning hops production
- *Benchmark*- Number of current growers and acreage identified through Nebraska Hop Association
- *Target*- A 10% increase in hops acreage by existing growers and three new hops growers that have actively started the planning/implementation process

Goal 2 Measured Outcomes

Identification of the number of growers and the actual amount of acres in hop production proved to be difficult to accurately identify, however, the following is what we are able to determine and is conservative to what is most likely occurring:

- There were 17 specialty crop farmers identified as commercially growing hops in 2015 for a combined total of 12 harvest acres. Through development of the Nebraska Hops Conference (2016) and the leadership of an emerging industry processer (*Midwest Hop Producers,* Plattsmouth, NE), there are now 38 identified hop growers that had a combined total of 50 acres harvested in 2018. This reflects a 76% increase in harvest acres and a 55% increase in specialty crop growers. How much can be attributed directly to this project is difficult to identify however it is speculative that more than 10% of the increase in acreage and growers are related to impacts from this project.

Beneficiaries

Nebraska Hop Growers Association (NHGA) mission is to promote the growth & use of Nebraska hops as a sustainable crop through education and shared resources for commercial & home brewers.

Impacts: This organization was an informal group that met one or two times per year since about 2008. They officially organized as a non-profit in 2011. The UNL Hops team have encouraged the organization to become more professionally visible but have struggled as officers are volunteers and hold other jobs as their principle income. As the hop industry expands, it is hopeful that the NHGA will become the leading professional team. NHGA have supported the work that our project has done and often participated in our workshops.

Nebraska Craft Brewers Guild is a professional organization that fosters a Nebraska-centric community that is informed, enthusiastic and actively creating unity among its members on market and public policy issues to create the most business-friendly climate for craft brewers.

Impacts: The brewer's guild has been casual observers of the work being done by UNL Hops, NHGA, and Midwest Hop Producers. They have quality concerns over the general concept of NE being able to

have a viable hop industry. Members of the brewer's guild have independently used hop produced and are somewhat supportive but will continue to evaluate the potential through time. The guild have had leaders participate in the NE conferences and we have had some present at our field open houses.

Nebraska Grower and Brewer Conference & Trade Show's purpose is to provide pertinent educational information to regional hop growers and craft brewers, to provide a platform for participants to build industry connections and relationships, and to provide the resources, skills and tools for participants to contribute to the Nebraska hop growing and craft beer industries.
Impacts: The Nebraska Grower and Brewer Conference & Trade Show was created as a result of being awarded this specialty crop grant and the relationship with the emerging commercial hop grower/processer company, Midwest Hop Producers. The conference is moving into its 3rd year and had 172 involved in 2016 and 211 in attendance for 2017.

Midwest Hop Producers (Plattsmouth, NE) is Nebraska's leading independent hop company that has identified its mission as, "To establish a well-managed hop enterprise that provides farmers with a high-value crop that returns the majority of the crop value back to the growers, *and* provides high quality whole leaf and pelletized hops to everyone from craft brewers to home brewers while maximizing environmental stewardship through sustainable practices."

Impacts: Midwest Hop Producers are doing many different projects on their own and developed programs to help expand the hop growing industry. They have been highly supportive of the work we have done and compare our findings to that of theirs. The methodical process of our work does not meet their needs and they press forward based upon interaction with growers nationally and speculation. They value our outreach products and have had us participate in many of their events to support the emerging industry.

Lessons Learned

Nebraska is the 16th largest state in the U.S. and is more than 410 miles long, 210 miles wide, and covers more than 77,358 square miles. The intent of this project was to explore locations that potentially could have hops in production, based upon population and geographical conditions. Given the distance between the five trial sites, cooperators were necessary to handle routine tasks. Protocols were given but many times not administered as instructed as they did not understand the importance of following them concisely. Researchers attempted to be at each site weekly but weather conditions created variability in these visits. Harvests became challenging as the timing between the cultivars varied over a 4-week period. Additionally, the timing between determination of ready to harvest from test samples and actually doing that resulted in targets being passed.

Equipment for this project is specialized and at times availability for use was not convenient. Purchasing equipment was generally out of the question as it had limited use and was restricted by the granting agency. Much labor was done manually and could easily done until harvest period, which, coincided with start of fall semester classes. This resulted in challenges of hitting the target dates of harvest for all sites, especially with travel distances and impeding weather.

The high interest in this project was beneficial and created additional challenges. There was much publication through various forms of media that spread the word about this project and aided in getting participants in our educational programs and field days. It created challenges due to the heavy number of phone calls and email exchanges. For this reason, a staff member was identified to field the contacts and become the face of the project. This person supported the UNL Hops web presence, created the Nebraska Bine Times blog, and conducted many open houses across the state. Impacts

were tremendous and it is with this researchers hope that industry organizations will take over the future charge of what was started by this project.

This project does indicate that hops can be grown in NE but it will take many more years to better understand if a commercial industry can be validated. Given the environmental conditions are highly variable in comparison to traditional hop growing regions, developing an understanding of how to determine programming for cultural activities will take many years of trials and experience. The work conducted through this specialty crop project provided base knowledge for direction of future work in this area.

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Additional Information

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Images through University Communications (Web Presence)

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Above: Allison Butterfield, a graduate research assistant in horticulture, feeds a hop bine into a harvester during the Aug. 24 event.

Below: Katherine Kreuser talks about growing hops during a tour of the hop yard on Nebraska's East

Campus. Kreuser is the hop program coordinator for the university.

Below: UNL's Stacy Adams examines hops in East Campus test gardens during the 2015 growing season. A team of UNL researchers is testing the viability of growing hops in Nebraska.

Below: One of the study's five acreage locations. This is near Scottsbluff, looking west. (Photo courtesy Stacy Adams)

Project Title

Identify the Best Fenugreek Cultivar for Organic Production in Western Nebraska

Project Summary

Fenugreek (*Trigonella foenum-graecum* L.) is an annual legume, historically known in Asia as herbal medicine. Fenugreek seed possess a number of health-enhancing bioactive compounds such as (1) galactomannan, a major polysaccharide in fenugreek seed, (2) 4-hydroxyisoleucine, and (3) diosgenin, a steroidal sapogenin used extensively by both pharmaceutical and nutraceutical industries. These constituents seem to work synergistically to produce multiple health effects (anti-type2 diabetes, anti-cancer, anti-cholesterol, anti-migraine, and many others). Galactomannans and 4-hydroxyisoleucine are associated with anti-diabetic (type-2) through various mechanisms of actions, whereas diosgenin is associated with anti-cancer (colon, breast, prostate, and leukemic) properties. All these human health effect of fenugreek seed have placed fenugreek as one of the most commonly recognized 'nutraceutical' or health food products.

At present, the US medicinal and nutraceutical industry imports all fenugreek seed from other countries since there is no commercial production in the USA. 'Tristar', the only fenugreek variety in North America was developed and released by Agri-Canada for commercial hay production (i.e. not for seed). No fenugreek variety for high quality seed production is available not only in USA but in North America also. The US industry requires high quality (preferably organic) fenugreek seed. Preliminary research clearly showed western Nebraska can be an ideal location for high quality fenugreek seed production. The objective was to identify the best cultivar following optimal planting and harvesting time under conventional production condition for high seed yield and quality.

The short-term impact is the identification of high-yielding cultivars with high seed quality in western Nebraska and awareness of a high-value new crop in the region. The long-term impact of several years of research on this crop would be the development of fenugreek-based, small- and -medium scale nutraceutical industries in Nebraska.

Project Approach

After the first year of a fenugreek feasibility study under an organic production system, it was discovered that non-chemical weed management (i.e. no herbicide, no chemical fertilizer) was not feasible for fenugreek. Therefore, the goal of the project was revised to identify the best cultivar for high-quality fenugreek seed production under irrigated and non-irrigated land following conventional (non-organic) production systems. The project followed optimal planting and harvesting times under organic production conditions for high seed yield and quality.

Based on the past fenugreek study, the 12 best fenugreek lines were planted in replicated plots under non-irrigated (dryland) and irrigated conditions at Scottsbluff, Nebraska. Standard agronomic data (emergence, plant height, and flowering time) were measured. The plots were harvested. Seed is being cleaned and analyzed for quality attributes (test weight, seed size). The trial was shown at a field day to 53 industry representatives and questions were answered as they related to fenugreek production and marketing.

Planting and harvesting of cultivar evaluation for seed yield

Twelve fenugreek lines were planted in 4 replicated plots under non-irrigated and irrigated conditions at Scottsbluff, Nebraska in 2016 and 2017. The trials were planted as 8-row plots (5' x 25') with 7.5" row spacing using a seeding rate of 20 kg/ha. Trials were harvested in the fall of 2016 and 2017.

Agronomic practices

Sonolan at 4 oz/acre was used as a pre-plant herbicide and Raptor at 4 oz/acre was applied as a post-emergence herbicide in all trials. Approximately 0.25 inches of water was applied within 24 hours after planting to activate Sonolan and to allow for better plant emergence. After this initial irrigation, the dryland trial was not irrigated but irrigated trials were irrigated throughout the season. Total irrigation applied to the irrigated trial from planting to harvesting was 8.69 inches (2016) and 6.5 inches (2017). Natural rainfall was 6.22 inches (2016) and 5.41 inches (2017).

Data collection

Standard agronomic data (emergence, plant stand, flowering, and height (at maturity)) were measured. The plots were harvested and yield was estimated. Seed was cleaned and analyzed for quality attributes (test weight, seed size). Data analysis (ANOVA) was done using SAS 9.4. The results presented below above is based on averages of 2016 and 2017.

Goals and Outcomes Achieved

The 2016 data is shown in Table 1 (non-irrigation) and 2 (irrigated). Seed yield difference between the irrigated and non-irrigated trials was not significant although a few varieties were better under non-irrigation and vice-versa.

Table 1. Fenugreek variety testing data conducted under non-irrigation at Scottsbluff, NE. The trial was planted and harvested on May 20 and September 12, 2016.

Variety	Country	Yield Rank	Yield (lbs/a)	Test Wt (lbs/bu)	Flowering (DAP)	Height (inch)	Emergence (%)
Amber	Canada	1	2018	53	45	18	68
Tristar	Canada	2	1928	52	43	19	60
PI617080	Bulgaria	3	1899	54	35	14	75
PI543073	Pakistan	4	1770	53	42	16	52
PI183911	Unknown	5	1746	54	39	16	53
PI426970	Pakistan	6	1697	54	44	18	43
PI244060	Yemen	7	1661	52	39	13	80
PI170834	Turkey	8	1549	54	36	16	63
PI179058	Turkey	9	1536	53	35	16	48
PI617079	Bulgaria	10	1435	50	34	15	54
PI204527	Turkey	11	1417	53	40	16	55
PI568215	Turkey	12	1258	54	35	18	35
	Mean		**1659**	**53**		**16**	**57**
	LSD (0.05)		**490**	**1**		**3**	**23**

DAP = Days After Flowering

Table 1. Fenugreek variety testing data conducted under irrigation at Scottsbluff, NE. The trial was planted and harvested on May 20 and September 12, 2016.

Variety	Country	Yield Rank	Yield (lbs/a)	Test Wt (lbs/bu)	Flowering (DAP)	Height (inch)	Emergence (%)
PI244060	Yemen	2	2230	54	43	18	80
Tristar	Canada	3	2128	51	45	18	75
PI617080	Bulgaria	7	1925	53	38	14	75
PI170834	Turkey	9	1891	54	37	17	78
PI617079	Bulgaria	10	1839	54	36	17	74
PI183911	Unknown	12	1767	52	41	16	68
Amber	Canada	13	1740	52	43	20	80
PI543073	Pakistan	17	1677	53	43	17	72
PI204527	Turkey	20	1594	55	38	18	70
PI426970	Pakistan	21	1561	53	42	18	68
PI568215	Turkey	26	1449	55	36	19	68
PI179058	Turkey	28	1413	52	48	17	66
	Mean		**1743**	**53**		**18**	**73**
	LSD (0.05)		**450**	**1**		**3**	**15**

DAP = Days After Flowering

The 2017 trials appeared to look very strong throughout the summer in 2017. Plots were harvested late due to extended wet period from rain in September. Chemical weed management was very good. There was no disease and insect issue. Under irrigated conventional production system, four fenugreek lines, which are significantly better than 'Tristar', the only public variety in North America, were identified under irrigation. The lines produced high seed yield (ranged 1,779 lbs/acre to 1895 lbs/acre; trial av. 1,749 lbs/acre) with high seed quality (av. test weight 53 lbs/bu; av. 1000 seed weight 18 g). Average flowering date and plant height were 39 days after planting and 21 inches. Whereas, yield, test weight, seed weight, flowering, and plant height of 'Tristar' were 1507 lbs/acre, 51 lbs/bu, 49 days after flowering, and 17 inches, respectively. The seed of the four lines also had significantly higher bioactive health promoting compounds galactomannan (av.14%) and diosgenin (av. 2%) compared to that of 'Tristar' (11% and 1%).

Under non-irrigated production condition, the varieties performed very poorly under non-irrigation. Average seed yield and test weight were 906 lbs/acre and 46 lbs/bu, respectively. Plants were too short (av. 14 inches) to harvest mechanically. Therefore, seed of dryland trials were not analyzed for bioactive compounds.

Beneficiaries

The knowledge of fenugreek, its production potential, and available varieties were disseminated to target audiences, which consisted of growers, industry personnel, scientists, and the general public. The results were presented at the following venues.

1. High Plains Ag Lab Advisory Committee's Annual Meeting in February 2017 in Sidney, Nebraska. There were 25 people in attendance, which consisted of bankers and grain handling personnel.

2. High Plains Organic Crop Improvement Association field days in June 2018. The High Plains OCIA consists of 32 members.

3. Summer field days on June 21, 2017 and August 14, 2018 at the High Plains Ag Lab near Sidney, Nebraska.

4. Visit of Nebraska Leadership Team on September 16, 2017, in Scottsbluff, Nebraska. There were 28 in attendance, which consisted of growers, industry personnel, and governmental representatives.

It is expected that approximately 70 people were educated on fenugreek production. These include those who attended the events mentioned above. Information will be incorporated into the University of Nebraska's CropWatch web site (http://cropwatch.unl.edu/). The audience for the UNL CropWatch website will be measured by the number of visits to the site. The CropWatch web site receives over 10,000 visitors each year.

Lessons Learned

No new problem was there except the trials could not be conducted under organic production condition (same as in 2016) due to the following reasons. The trial was conducted under a conventional production system instead of an organic system as originally proposed. After the first year of a feasibility study, it was discovered that a non-chemical weed management is not feasible for fenugreek after under an organic system (i.e. no herbicide, no chemical fertilizer). This was not expected when the project was originally proposed. Therefore, the goal of the project changed from an organic production system to a conventional production system.

The high seed yielding varieties identified under conventional production system will possibly perform similar under organic production system if the farm is free from weed seed bank and if excellent non-chemical weed management is followed. Organic fenugreek production may be difficult on field with poor mechanical weed management since fenugreek is slow growing at early stage.

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Additional Information

The data was presented at field days and regional extension meetings. At least one UNL Extension article (extension journal or newspaper) will be prepared and published. Although it is not part of the current grant, an initiative will be taken to explore the USA market, which is the major bottle neck of bringing fenugreek into commercial production.

Project Title

Impact of Fenugreek Seed on Gut Bacteria Population Changes and Their Effects on Host Metabolic Diseases

Project Summary

Metabolic syndrome is a cluster of chronic metabolic diseases, including obesity, diabetes, cardiovascular disease, and fatty liver disease. Among the adults in the U.S., the prevalence of obesity is 20 to 30%, type 2 diabetes is 10%, and fatty liver disease is 25%. This pandemic has posed substantial health risks in the U.S. and imposes an enormous economic burden on the U.S. health care system. Thus, developing the nutritional-based therapeutic approaches is a timely topic as the nation faces a metabolic disease epidemic.

Fenugreek (*Trigonella foenum-gracecum L*), an annual legumes, is adapted to semiarid dryland environment and under limited soil-moisture condition. A number of health-enhancing bioactive compounds have been reported in fenugreek seed and leaves, including Diosgenin, Galactomannan, and 4-Hydroxyisoleucine. These compounds synergistically exert multiple beneficial effects on the host health, including lowering blood glucose and cholesterol levels in the test animals. Fenugreek was reported to affect gut bacteria in fenugreek-based feeding trial of piglet and chicks. The medicinal nature of fenugreek has placed this oldest plant as one of the most commonly recognized 'nutraceutical' and may serve as a prebiotic to promote the population of beneficial gut bacteria in subjects with obesity, diabetes and fatty liver disease.

Over the past few years, Alternative Crops Breeders at the University of Nebraska's Panhandle Research and Extension Center have developed high-yielding fenugreek cultivars with high level of bioactive compounds. However, little was known about the pharmaceutical effect of the Nebraska-grown fenugreek in vivo. Therefore, the purpose of this project is to determine the impact of fenugreek seed and its bioactive compounds on gut bacterial population restructure and their effects on obesity, fatty liver disease and insulin resistance.

Project Approach

During the grant period, we have determined the medicinal values of Nebraska-grown fenugreek seed in mouse models with hyperlipidemia and insulin resistance. We found that a diet containing as low as two percent (2%) of Nebraska-grown fenugreek seed potently reduced lipids and inflammatory cytokine (TNF□) in the circulation bloodstream, and promoted systemic insulin sensitivity in the insulin resistance mouse models. Fenugreek containing diet further stimulated the populations of beneficial gut bacteria, such as *Akkermansia muciniphila*. Using molecular biology approaches, including quantitative-reversed transcript-PCR and immunoblotting analysis, we delineated the underlying molecular mechanism of fenugreek seed on host health was via inhibiting the activation of a liver master transcription factor SREBP-1c and the subsequent de novo lipid synthesis by enhancing expression of insulin-inducible gene-1 (Insig-1) and gene-2 (Insig-2). mRNA expression of PPAR□□□an important transcription factor that regulates mitochondrial function and fatty acid □-oxidation, □and its downstream target genes were also upregulated in the fenugreek seed fed-mice. These actions resulted in significantly reduced hepatic lipid accumulation and very-low density lipoprotein (VLDL) secretion, improved endoplasmic reticulum (ER) stress and ameliorated metabolic inflammation. They further stimulated the population of beneficial gut bacteria (*Akkermansia muciniphila*) and enhanced insulin sensitivity and improved hyperlipidemia. In vitro, treating a rat hepatoma cell line, McA-AH7777, with trigonelline, a bioactive compound in fenugreek seed, was able to recapitulate the results observed

in vivo. These results demonstrated that fenugreek seed is able to inhibit hepatic lipid synthesis and VLDL overproduction and ameliorate insulin resistance.

These novel findings have been presented at the *Arteriosclerosis, Thrombosis, and Vascular Biology* annual scientific conference in May 2016. There were about 1,500 attendees at this event. About 90% of the attendees were researcher scientists from academic institutes and the remaining 10% were from pharmaceutical industry and media. Many of the attendees expressed their high interest in our research work. They asked information about the availability of Nebraska-grown fenugreek seeds and planned to include fenugreek seed in their food. The research result of this project has also been submitted to a high impact international journal, "Molecular Nutrition & Food Research**,"** and was accepted for publication.

The Co-PI of this project, Dr. Dipak Santa, contributed the Nebraska-grown fenugreek seeds for this project. Dr. Santa is an alternative crops breeder at the University of Nebraska's Panhandle Research and Extension Center. He has been actively developing high-yielding fenugreek cultivars with high level of bioactive compounds over the years.

Goals and Outcomes Achieved

The goal of this project was to promote human health by determining the medicinal value of Nebraska-grown fenugreek seed and disseminating the health beneficial effect of fenugreek seed to the US citizens through public media, such as scientific conferences and scientific publication.

During the funding period, we have completed the following activities to fulfil this goat.

- Establishing the hyperlipidemia and insulin resistant mouse models for this project.
- Determining the impact of Nebraska-grown fenugreek seed on high-fat diet induced systemic inflammation, circulating lipids and insulin sensitivity.
- Characterizing the molecular mechanism of Nebraska fenugreek seed on regulating lipid and lipoprotein metabolism.
- Determining the population changes of beneficial gut bacteria upon exposure to fenugreek containing diet.

Measurable outcomes for the project

- We have demonstrated that a diet containing as low as two percent (2%) of Nebraska-grown fenugreek seeds is sufficient to reduce inflammation and hyperlipidemia induced by high-fat diet or genetic depletion of a transcription factor CREBH. Fenugreek seed feeding further improved insulin sensitivity in high-fat induced insulin resistance mouse models.
- Nebraska fenugreek seeds prevented hepatic cellular stress induced by high-fat diet or CREBH depletion.
- Nebraska fenugreek seed enhanced hepatic fatty acid β-oxidation and reduced VLDL assembly and secretion. This action prevents the hyperlipidemia induced by high-fat diet and CREBH depletion.
- Fenugreek seed feeding stimulated the population of beneficial gut bacteria, *Akkermansia muciniphila.*

This is a two-year project. All research activities and outcomes proposed in the approved proposal were completed. The goals and targets have been met.

Beneficiaries

The novel research finding from this project demonstrated the Nebraska-grown fenugreek seed possess the medicinal value of anti-obesity and anti-diabetes. This scientific evidence may land support for promoting the development of fenugreek as a specialty crop in Nebraska and a prebiotic supplement for the prevention and treatment of obesity and diabetes.

Dissemination of the research results in the ATVB conference and via the peer-reviewed publication in a high impact international journal, ***Molecular Nutrition & Food Research,*** will raise the awareness of the US citizens about the health beneficial effect of fenugreek seed. This will promote the development of nutritional based strategies for the prevention and treatment of metabolic syndrome.

Funding of this project has also supported the research of a graduate student who is going to obtain his Master's degree in December 2017.

Lessons Learned

This project, for the first time, reveals the triglyceride lowering effect and the anti-diabetic effect of Nebraska-grown fenugreek seed.

It further unveils a novel role of fenugreek seed in preventing metabolic inflammation and metabolic diseases, such as obesity, fatty liver disease and diabetes.

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Project Title

Extrusion Processing of Dry Edible Beans to Retain Folic Acid Concentration

Project Summary

Even with mandatory fortification of wheat flour with folic acid, 9% of adults still consume less than the estimated average requirement for folic acid. Dry edible beans are an excellent source of folic acid (140-170 µg/serving or 35-42% of the recommended daily value). The main objective of this project was to determine the effects of extrusion parameters (moisture, screw speed, temperature) on folic acid retention in the extruded snack product. Our results showed that moisture content was the most significant factor affecting folic acid concentration in Great Northern Bean (GNB) on extrusion, with lower moisture contents resulting in greater folic acid degradation. This project built on our previous SCBGP grant where we reported on the dialyzability of magnesium from extruded GNB flour. In that previous project, we found that low moisture content led to greater magnesium dialyzability. Although these were the conditions that resulted in the greatest folic acid degradation, the loss in folic acid was moderate compared with other processing techniques. Therefore, extrusion of GNB flour to produce ready-to-eat snack products that meet the nutritional needs of Americans seems feasible. This project could impact the approximately 1,700 dry bean producers and the 15 dry bean processors in Nebraska by creating increased demand for their crop.

Project Approach

GNB flour was extruded using a twin-screw lab scale extruder at different levels of flour moisture (MC, 17-25%); screw speed (SS, 156-250 rpm); and barrel temperature (T, 90-140 °C) using an inscribed central composite rotatable design. Extruded samples were milled into flour using hammer mill and stored under refrigerated conditions until further analysis. Folic acid was measured in both un-extruded bean flour and extruded samples using a microbiological assay.

Folic acid concentration in extruded bean samples ranged from 1092 to 1202 mcg/kg sample compared to 1430 mcg/kg in the unprocessed GNB flour. On an average, there was a 20% reduction in folic acid in extruded bean samples when compared with un-extruded flour. Moisture content was found to be the most significant factor affecting folic acid content in GNB on extrusion with a prominent quadratic effect. In particular, at the lowest moisture content, 17%, there was a 24% loss in folic acid compared to only a 15% loss at the highest moisture content, 25%. Surprisingly, moisture content had a greater influence on folic acid degradation than barrel temperature. Based on previous research, the results suggest that extrusion results in better folic acid retention compared to traditional processing methods for beans. We coupled these results with our previous findings on magnesium dialyzaibility during extrusion of GNB. We found that a barrel temperature of 100 °C, moisture content of 20.7% and screw speed of 245 rpm were the optimum processing conditions to achieve minimum loss in folate while promoting high element dialyzability in GNB flour. This suggests low temperature, medium feed moisture content, and high screw speed are ideal processing conditions to retain nutritional values in GNB.

Goals and Outcomes Achieved

The original objectives were to determine optimum parameters for extruding dry edible beans under high shear, high temperature conditions and low shear, low temperature conditions to increase folic acid retention. We found that folic acid degradation is relatively minor during extrusion of GNB, with a maximum of 24% loss at very low moisture conditions. Coupled with our previous findings on magnesium dialyzability, these results show that extrusion is a feasible processing strategy to obtain ready-to-eat snack products while enhancing dialyzability of magnesium and retaining folic acid.

Beneficiaries

The results of this project was presented at an annual meeting of the American Association of Cereal Chemists International, which consisted of approximately 1,000 attendees. Additionally, these results were published in a peer-reviewed journal.

The public is also a beneficiary of this research. Providing snacks from beans that have enhanced magnesium bioaccessibility could have a positive impact on magnesium nutritional status of Americans.

Another beneficiary are dry edible bean producers. Increased demand for dry edible beans will benefit the economy in the panhandle of Nebraska, where dry edible bean production is an important part of the economy. The benefits to these parties will be realized through continued efforts in dry bean research and promotion.

Lessons Learned

The most important finding from this work was that folic acid is minimally affected by extrusion. Other researchers have reported >90% reduction in folic acid during traditional processing, while we found a maximum of 24% reduction in folic acid during extrusion at low moisture contents. At high processing moisture, reduction was even less, at only 15%. Surprisingly, processing temperature had only a minor effect on folic acid degradation.

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Additional Information

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Project Title

Alternative Tillage Methods and Specialty Crops: Education, Research, and Awareness

Project Summary

This project was designed to help small scale vegetable producers increase the yields of specialty crops by exploring and demonstrating alternative soil preparation practices that preserve soil structure. Rototilling multiple times in a season, as is common in specialty crop production, destroys soil structure and soil biology that is essential to sustainable production of specialty crops. Alternative tilling methods, like broad forking and power harrowing, can keep soil structures intact, providing a more beneficial climate for nutrient retention. Some nutrients, primarily nitrogen, are not maintained within the soil after rototilling largely due to the exposure of organic matter. Organic material, when exposed to air and sunlight, loses many of its essential nutrients. The valuable nutrients dissipate without providing any benefits to the soil.

The relevance and timeliness of this project is clear due to the limited access to land most small-scale specialty-crop producers experience. This limited access increases the importance of high yields and healthy soils, especially in an expanding market with high consumer demands both in Nebraska and across the country. Wholesale markets, in particular, are growing and specialty crop producers are looking for ways to maximize their production to meet these demands.

Project Approach

2016

In January, Farm Program Manager, Matt Pirog, attended the Practical Farmers of Iowa Conference. Farm Production Coordinator, Aaron French, attended the Nebraska Sustainable Agriculture Society Annual Conference.

In February, soil samples were collected from the test plot area to establish baseline data. Soil was tested using the Haney Soil Testing procedure, which analyzes the biological potential of soil. In 2017 and 2018, the individual test plots will be tested separately. Based on the fact that the alternative tillage supplies does far less destruction of soil structure, it is expected to see the soil health indicators in those plots rise, while the plots prepared using conventional tillage techniques will decline.

This project was designed to help small scale vegetable producers increase the yield of specialty crops by preserving the soil structure of their land. Rototilling continuously disrupts the soil structure that is beneficial to specialty crops. Alternative tilling methods, especially replacing plowing and tilling with rotary plowing and power harrowing, can keep soil structure intact, therefore, providing a more beneficial climate for nutrient retention. Consequently, the supplies necessary for completion of this project were purchased in February. These items included the rotary plow, power harrow, broadforks, and the precision vegetable seeder. Items are for use in the demonstration plots for research and to teach farmers who come to the farm.

In late April, 4 beds were established as test plots. Two control beds were formed using traditional vegetable production techniques of discing, bed shaping, and tilling. The other 2 beds were prepared as test plots using the supplies purchased.

The procedure for shaping the test plots was as follows:

1. One pass down each side of the bed with the rotary plow to create a raised bed;

2. One pass down the bed with the broad fork to loosen and aerate soil; and

3. Final bed preparation was completed with a pass using the power harrow.

We introduced these tools to 10 beginning farmers at our training farm site in April. Instruction was provided on maintenance, operation, and benefits of these implements over the traditional rototiller attachment.

In early May, all 4 test plots were covered with biodegradable plastic mulch and planted with onion starts. In July, the pressure from annual grasses in the test plots was very high and the plastic mulch did very little to control that pressure. All plots were cropped out and yield data was not recorded due to the major pressure from weeds.

2017
In March, soil samples were collected from the test plots and compared with the baseline data from 2016. There were no significant changes in the soil health indicators from the 2016 baseline. Soil was tested using the Haney Soil Testing procedure, which analyzes the biological potential of soil. It is well understood that the effects of soil tillage management changes do not usually manifest themselves in the first year following the changes.

In April, the test plots were planted with radishes and yield data was collected from each bed. Beds were harvested until June. The yield difference from each plot was negligible and the management changes have not had any apparent effect on yield at this time.

A subsequent cover crop seeding failed to establish and the beds were left to be grown over by annual grasses until they were prepared for planting again using the same methods described above. The beds were then planted with radishes in late September.

Goals and Outcomes Achieved

The first goal of this project was to educate specialty crop producers on the importance of maintaining heathy soil structure. Tools were introduced to 10 beginning farmers at our training farm site in April 2016. Instruction was provided on maintenance, operation, and benefits of these implements over the traditional rototiller attachment.

In June 2017, we hosted a workshop/farm tour for 12 beginning specialty crop producers to demonstrate the alternative tillage equipment and talk about the advantages of minimal tillage techniques. The equipment was on display at another workshop we hosted in October 2017. At this workshop, the use of the rotary plow to construct a raised beds while maintaining soil structure was demonstrated. Four producers were in attendance for that workshop.

In 2016 and 2017, we provided educational opportunities for beginning farmers to learn about alternative tillage practices and the beneficial effects they have on soil health. We also conducted side-by-side comparison trials of two different soil preparation techniques and measured yield differences and changes in soil testing parameters to test what effect tillage practices would have on soil health.

In 2018, 13 aspiring farmers were introduced to these implements through our Growing Farmers Training program. Participants learned about the importance of soil biology and soil structure in the classroom then got a chance to see alternative tillage options and practice their use.

Through 2018, the beginning specialty crop producers at the Prairie Pines Training Farm have logged over 100 hours of use of the power harrow for operations that would have previously been completed using a rototiller.

The educational workshops for this project were administered by Matt Pirog, Growing Farmers Program Manager at Community Crops. Field trials and demonstration plots were overseen by Aaron French, Farm Production Coordinator at Community Crops.

The second goal of this project was to increase yields of specialty crops through alternative tillage methods. Alternative tillage methods were utilized in a demonstration plot adjacent to a traditionally tilled plot to showcase and monitor how the yield is affected by tilling. Past soil tests were used to establish a baseline for nutrient levels and organic material content. This information was used to prove that that by using a rotary plow, power harrow and broad fork the levels of beneficial nutrients and organic matter can be increased. We conducted soil tests to measure the actual increase in beneficial nutrients and organic matter. There have been no significant differences in soil tests or yield results of the demonstration plots. Side-by-side comparison trials and soil testing will continue in 2019. See above for more details regarding how this goal was accomplished.

The third goal of this project was to educate the public of specialty crops and alternative tiling methods. In 2016, 2017, and 2018, we hosted our annual Feast on the Farm fundraising event to showcase the alternative tillage equipment and educate attendees on the benefits of alternative tillage techniques. Approximately 700 people from the general public attended this event over the life of this project. Farm tours were provided to attendees and the two-wheel tractor, power harrow, and rotary plow were on display. As part of the tours, information was shared with this group about the benefits of alternative tillage and the drawbacks of the use of conventional rototillers and their respective impacts on soil structure and health.

Beneficiaries

Beneficiaries of this project include beginning specialty crop producers in Southeast Nebraska who want to learn more about alternative tillage and soil health. This equipment will continue to be available for use by farmers-in-training at the Prairie Pines Training Farm.

Lessons Learned

One important lesson is that two years was too short of a time frame to evaluate changes in soil health based on tillage practices. We will continue these comparison trials in 2019 and monitor for any changes in soil health indicators.

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Project Title

Winter Greenhouse Production of Medicinal Herbs

Project Summary

The purpose of this project was to create a model growing system (standardized, repeatable) for medicinal herb production during the winter months. With a model system in place, we projected that you could predict how many plants (specifically leaves) were needed to obtain the medicinal product and what kind of environmental factors needed to be controlled to do so. If that can be accomplished, then a grower could apply for FDA or USP (oils) certification to insure product quality of plant-based supplements.

Project Approach

Five experiments were run using a similar calendar time over 3 years. The first year spanned September through April. The second and third years spanned September through December and January through April. This adjustment was made to reduce heating costs. The model system, a cost effective double polyethylene Quonset-style greenhouse, consisted of two lath/cinder block benches with a capillary mat fertigation system sandwich on top. The sandwich consisted of black plastic on bottom, fibrous mat and panda plastic (black on bottom/white on top-to increase light reflection) with drip tape below the panda layer. The drip tape distributed a base amount of fertilizer (100 ppm N from 20-10-20) and was controlled by an automatic irrigation system. Heat was supplied from a forced air natural gas furnace through poly tubes underneath the benches. Holes the diameter of the pots were cut into the panda plastic to allow direct connection of the pot base to the mat. All plants received only natural and day length light. Initially 8 cultivars were trialed. An additional 8 were added after the first year. Seeds were sown and transplanted into 8-inch/2-gallon containers containing a commercial peat-based mix (1 peat, 1 perlite, 1 vermiculite). Plants were harvested just before/as they were flowering, separated into parts, dried, weighed and leaves/tops were distilled for essential oils. Data were taken on light, air temperature, soil moisture, soil temperature and electrical conductivity. Adjustments to the containers for germination, timing of planting/pinching/harvesting and fertilizer levels were made to determine the best growing conditions. Additionally, tissue culture of 'Holy' ("tulsi") basil (leaves used as a tea for stomach ailments in India) was attempted but did not perform well in our greenhouse trials.

Basil Production Calendar (fall season) for Essential Oil Production

Model system. Double polyethylene greenhouse; heat under pots/benches; fertigation system of capillary mat sandwich (black poly on bottom, fiber mat, with drip lines, top poly is Panda plastic (white top/black bottom) using automatic irrigation clock. Dosamatic injector set at 1:100. No supplemental lighting. Day/night temperatures were set at 70 ^{o}F/65 ^{o}F.

Timeline	Activity
Day 1 - Sow seed late September	Sow seed into 3" peat pots (2 per pot); Mix is 1peat:1perlite:1 vermiculite. Set into trays. Water as needed. Germination 4-7 days. Prick out to 1 plant
Day 22	Transplant 3 plants per 2-gallon (8" container with drainage holes on the bottom). Mix is 1peat:1perlite:1 vermiculite. Add 18 g Osmocote Bloom 12-7-18 one inch below pot surface in each pot. Cover with mix. Panda plastic should have holes cut into it so pot base is in contact with mat or

	use commercial capillary mat. Start automatic irrigation system – twice a day – morning and early afternoon to run 3 minutes or until mat is saturated.
Day 29	Start fertigation. Mix up 100 ppm N of 20-10-20 fertilizer for injector. Apply preventative fungicide drench to pots
Day 43	Watch for flower buds and pinch off if they appear
Day 50	Pinch all plants leaving 3-4 leaves Fertigate with 50 ppm magnesium sulfate instead of 20-10-20
Day 57	Switch fertigation back to 20-10-20 100 ppm N
Day 64	Fertigate with 50 ppm magnesium sulfate
Day 71	Switch fertigation back to 20-10-20 100 ppm N
Day 86	Harvest and dry plant tops (including flowers if present)

Basil Production Calendar (spring season) for Essential Oil Production

Model system. Double polyethylene greenhouse; heat under pots/benches; fertigation system of capillary mat sandwich (black poly on bottom, fiber mat, with drip lines, top poly is Panda plastic (white top/black bottom) using automatic irrigation clock. Dosamatic injector set at 1:100. No supplemental lighting. Day/night temperatures were set at 70 ^{o}F/65 ^{o}F.

Timeline	Activity
Day 1 - Sow seed late January	Sow seed into 3” peat pots (2 per pot); Mix is 1peat:1perlite:1 vermiculite. Set into trays. Water as needed. Germination 4-7 days. Prick out to 1 plant
Day 29-36	Transplant 3 plants per 2-gallon (8” container with drainage hole on the bottom). Mix is 1peat:1perlite:1vermiculite. Add 18 g * Osmocote Bloom 12-7-18 one inch below pot surface in each pot. Cover with mix. Panda plastic should have holes cut into it so pot base is in contact with mat or use commercial capillary mat. Start automatic irrigation system – twice a day – morning and early afternoon to run 3 minutes or until mat is saturated. .
Day 37-42 (1 week after transplant)	Start fertigation. Mix up 100 ppm N of 20-10-20 fertilizer for injector. Apply preventative fungicide drench to pots
Day 44-49	Watch for flower buds and pinch off if they appear
Day 51-58	Pinch all plants leaving 3-4 leaves Fertigate with 50 ppm magnesium sulfate instead of 20-10-20
Day 58-65	Switch fertigation back to 20-10-20 100 ppm N *may need to add additional irrigation time at 3 PM if very sunny
Day 65-72	Fertigate with 50 ppm magnesium sulfate

Day 72-77	Switch fertigation back to 20-10-20 100 ppm N
Day 79-84	Harvest and dry plant tops (including flowers if present)

*Cultivars Aromatto, Elidia and Mrs. Burns' Lemon grew best with 9 g Osmocote Bloom/pot

From Table 1 plus data from all experiments, we determined that in the fall for pesto basils, 3 to 4 pots (9-12 plants) would need to be grown in order to produce the minimum 100 g dry weight (herbage) needed to extract basil oil from its leaves/flowers. For the specialty basils, two of the cultivars (Amethyst and Sweet Thai) did not grow well enough to produce enough dry weight for oil distillation. For 'Lime', 'Cinnamon' and 'Kapoor Tulsi', 2-4 plants were needed.

Table 1. Leaf Dry Weight of Specific Cultivars for Essential Oil Production (fall season)

Cultivar	Dry weight per 3 plants/pot (grams)	Number of pots needed for 100 g
Amethyst	1.24-5.40	> 16
Sweet Thai	2.41 – 27.6	>16
Dolly*	20.31-40.96	3-4
Cinnamon	28.4-50.14	2-3
Eleanora*	10.38-31.57	3-4
Lime	3.55-32.5	4+
Napoletano*	16.5-42.47	3+
Kapoor Tulsi	6.13-39.49	3+

*Common pesto basils for culinary use

In the spring, only cultivars of Red Rubin (specialty) and Genovese (pesto) required more than 2-3 pots (6-9 plants) to produce enough dry herbage for essential oil analysis (Table 2).

Table 2. Leaf Dry Weight of Specific Cultivars for Essential Oil Production (spring season)

Cultivar	Dry weight per 3 plants/pot (grams)	Number of pots needed for 100 g
Aroma-2*	50.50-81.69	2
Mrs. Burns' Lemon	3.12-68.99	2-3
Elidia*	3.91-71.88	2-3
Genovese*	0.56-29.32	>16

Aromatto	29.4-65.34	2-3
Italian Large Leaf*	4.73-76.43	2-3
Nufar*	12.06-55.56	2-5
Red Rubin	0.26-23.04	>16

*Common pesto basils for culinary use

The low cost ($32,000 complete set up including new greenhouse, propane heating, benches etc. see website for instructions) labor saving model growing system allows for growth of successful fresh herbage and dry herbage of 7 pesto and 5 specialty basils.

Table 3. Essential Oil Production of 16 Basil Cultivars

Approximately 235 distillations were run with leaves or leaves + flowers (tops) from 15 basil cultivars grown using the model system (Table 3). Of the 235 distillations, 101 gave enough sample (must be > 0.1) for composition analysis using GC-MS. If the flowers were added to the leaves, the essential oil quantity increased substantially.

Cultivar	Basil type	Oil produced from leaves (ml)	Oil produced from Leaves and flowers (ml)
Amethyst Improved	Purple pesto	<0.10	
Aroma-2	Pesto	0.10-0.30	0.30-0.75
Cinnamon	Asian		0.5-0.8
Dolly	Pesto	0.1-0.45	2.00
Eleonora	Pesto	0.10-0.20	
Elidia	Pesto	0.10	
Genovese	Pesto	0.10-0.30	0.80
Kapoor Tulsi	Asian	0.10	
Lime	Citrus	0.3 - 0.4	
Napoletano	Pesto	< 0.10	
Spicy Globe	Fine leaf	0.10	0.60-1.90
Sweet Thai	Asian		0.35
Italian Large Leaf	Pesto	0.10	0.10-0.40

Nufar	Pesto	0.10-0.15	
Red Rubin	Specialty	<0.10	
Aromatto	Specialty		0.10-0.50

Table 4. Essential Oil Composition of 14 Basil Cultivars

Of the 101 samples attempted using the GC-MS, 92 gave results. The results are in terms of Peak areas (Log 2) for each compound identified. These peaks predict relative amounts of the chemicals - not actual concentrations and thus should be used only for comparing among cultivars.

		Range of Peak Areas (Log 2)			
Cultivar	Number of samples	Eugenol	Estragole (methyl chavicol)	Linalool	Eucalyptol
Aroma-2*	11	14.45-27.18	14.32-19.97	18.06-25.81	22.20-23.28
Dolly*	8	14.02-26.67	15.36-17.89	18.88-25.77	22.02-23.60
Italian Large Leaf*	8	13.11-26.64	22.33-28.59	19.00-25.50	21.93-24.08
Genovese*	7	12.88-26.91	17.47-22.10	18.90-25.82	21.98-24.62
Nufar*	7	20.44-24.63	24.81-27.98	25.14-25.77	21.65-23.38
Eleonora*	1	22.25	18.55	24.61	22.38
Elidia*	1	26.98	19.83	25.53	23.08
Mrs. Burns' Lemon	28	13.62-22.87	15.41-23.01	18.85-26.06	16.89-21.36
Aromatto	7	17.03-19.43	29.00-29.62	21.30-24.85	22.03-24.61
Cinnamon	6	19.32-25.29	20.91-26.88	23.91-25.25	21.14-23.07
Spicy Globe	4	25.20-25.73	16.30-17.23	24.96-25.12	23.88-24.30
Lime	2	19.37-20.57	23.91-23.95	22.59-23.95	----------
Kapoor Tulsi	1	26.27	25.97	19.64	22.13
Sweet Thai	1	16.62	28.52	------	22.97
Commercial Oil	1	16.08	29.62	21.30	24.61

*Pesto basil. Basil cultivars Napoletano, Red Rubin and Amethyst did not yield any oil

For eugenol, all cultivars had relative quantities between 12 and 27. Estragole (methyl chavicol) relative amounts ranged from 14-28 (Table 4). Linalool relative quantities ranged from 18-26. Given that these measures are areas indicating relative quantities, there does not appear to be a difference among these cultivars in terms of essential composition. Basil cultivars Aromatto, Spicy Globe and Nufar showed particularly tight ranges for each of the chemicals identified indicating this model system may indeed allow for repeatable production and USP certification.

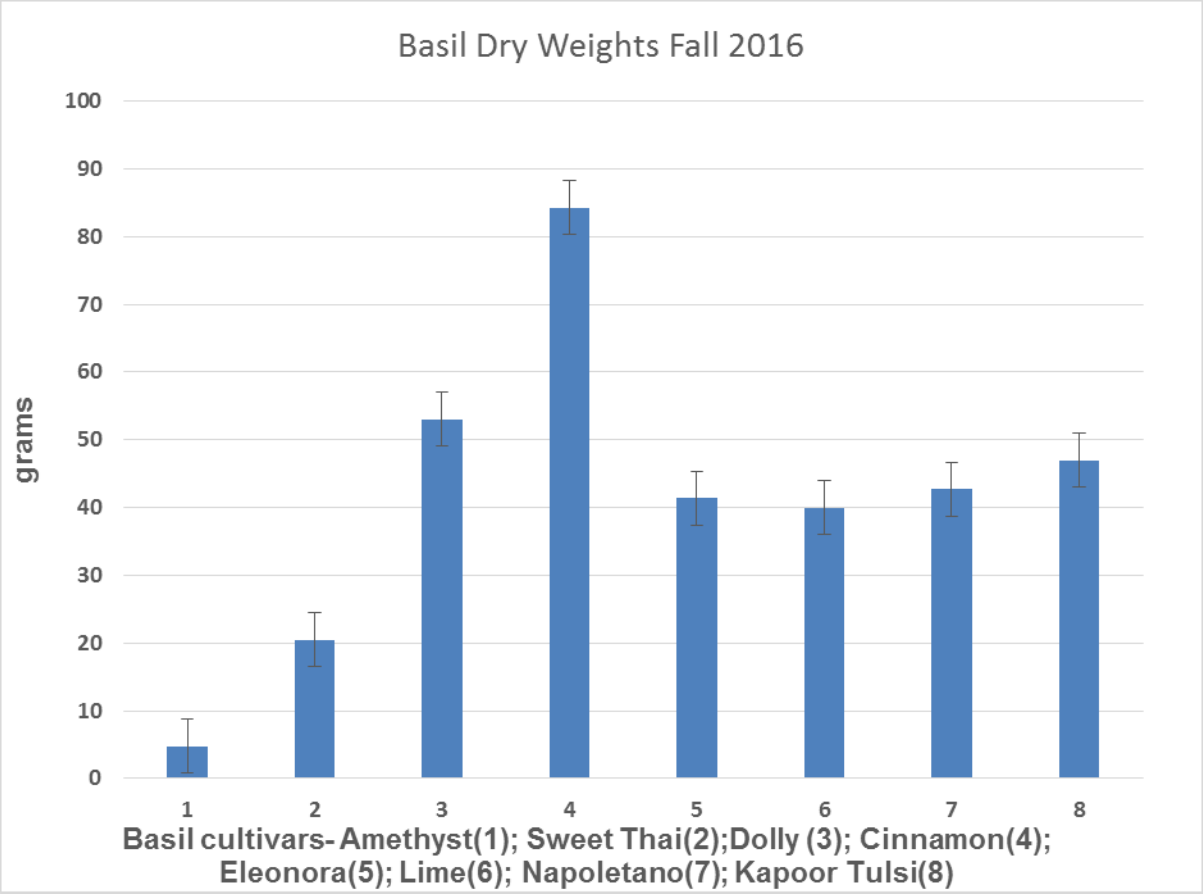
Basil leaves alone, particularly pesto basils, do not produce enough oil to distill. Current fresh basil production does not usually include flowers. Therefore, another method of using damaged/unsaleable fresh basil needs to be sought. Pesto paks (frozen) are current solution, but all damaged herbage still can't be used. Use of this model production system from seed to flower may allow for USP certification of basil essential oils.

Goals and Outcomes Achieved

It appears that growing in peat pots could be better than just sowing in cell paks (Fall 2015) as it allowed for transplant 21 days after sowing versus 43 days (Fall 2016). However, the longer germination time could also be due to different cultivars and sowing in August (higher temperatures) rather than sowing in September. We don't think this difference is due to cultivar as three of the cultivars have been used previously and did not take this long to germinate. Thus, it may be due to high temperatures. Supporting this conclusion is that days from transplant to harvest were 63 days fall 2015 versus 68 days fall 2016. We started earlier because we felt we would get more biomass. Thus, we recommend either sowing in a specific germination area with temperature control or waiting until September to germinate seeds in a greenhouse.

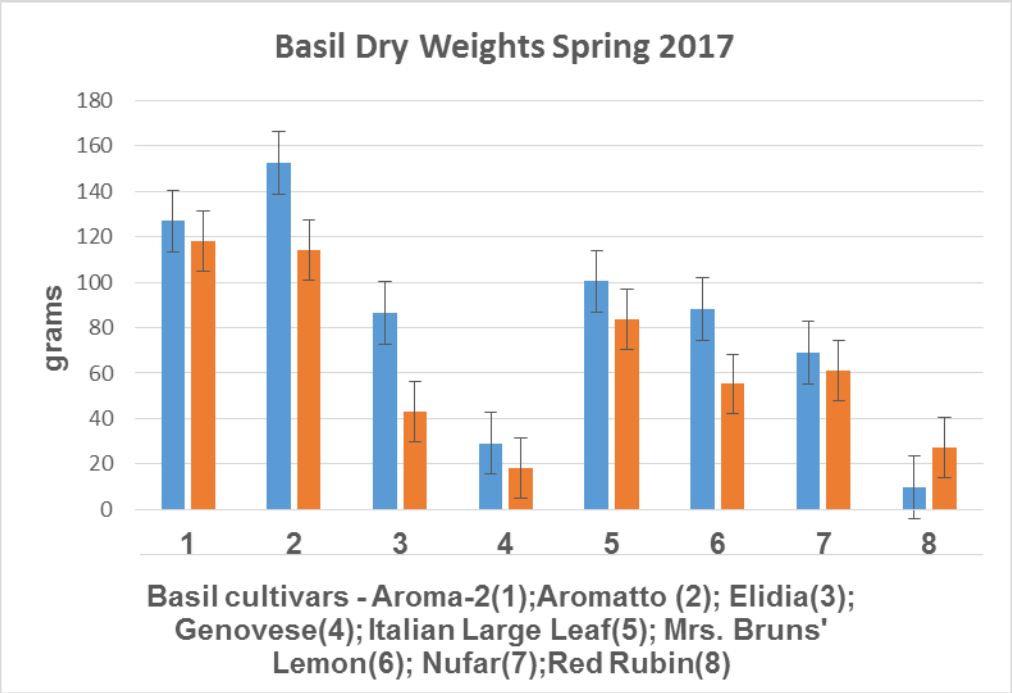
For spring 2017, germination was similar (30 versus 32 days) but production time was very different (49 days in spring 2016 and 70 days spring 2017). In the spring we control the temperatures and thus good germination time. The growth period however was longer this year and may be due to the additional cultivars not trialed previously (16 total –11 unique to the 2016-2017 growing season). We added these other cultivars because of the wide range of oil values that were recovered from the original representative cultivars of both pesto and specialty basils.

Experiment 4 (Fall 2016) and 5 Spring 2017)
Over these 2 experiments, we tested 16 different cultivars and found different growth patterns within both the pesto and the specialty basils. In the fall experiment, in terms of plant biomass expressed as total dry weight, there was no significant difference between the two fertilizer levels for any cultivar. However, there was a difference in total dry weight among the 8 cultivars tested (Graph1) with 'Cinnamon', a specialty basil, out performing all other cultivars. 'Dolly' (the commercially grown basil in Nebraska) and 'Eleonora', both pesto basils, gave similar growth responses to 'Lime', 'Napoletano' and 'Kapoor Tulsi', the specialty basils but did not produce as much biomass. This has implications for the number of plants/pots needed to produce oil.



Graph 1. Dry weight LSMeans plus/minus standard error for 8 cultivars grown during fall 2016.

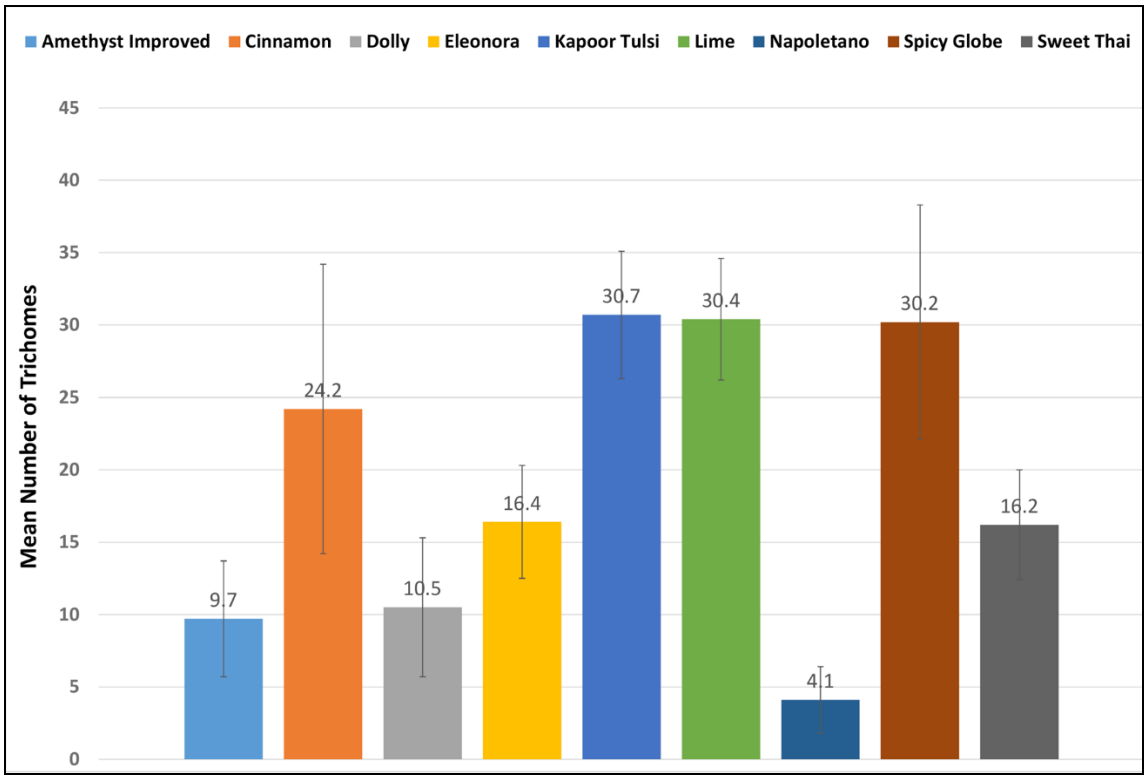
In the spring 2017 experiment, in terms of total dry weight, there was a significant difference between the two fertilizer levels for certain cultivars. 'Aromatto', Elidia' and Mrs. Burns' Lemon all produced the most biomass when plants received 9 g of Bloom 12-7-18. There was also a difference in total dry weight among the 8 cultivars tested (Graph 2) with 'Aroma-2' and 'Aromatto' outperforming all other cultivars. Thus, looking over 5 experiments, we conclude that 9 g of osmocote Bloom 12-7-18 at potting plus fertigation with 100 ppm N from 20-10-20 can be recommended for basil production of certain cultivars using the cap mat system.



Graph 2. Dry weight LSMeans plus/minus standard error of the difference for 8 cultivars grown during spring 2017. The blue bar represents plants receiving 9 g of Bloom osmocote 12-7-18 and the orange bar represents plants receiving 18 g.

Oil and trichome observations

For all cultivars tested, oil trichomes were found on both the adaxial and abaxial with more trichomes on the abaxial (Figure 1). In some instances the adaxial trichomes were harder to see and fewer in number than those on the abaxial. Using confocal microscopy, it was determined that there was more than one type of oil trichome present (Figure 2). Why that is we are not certain, but are checking more literature. In general, the mean number of trichomes on the abaxial side varied greatly from sample to sample as evidenced by the standard deviation bars (Graph 3). This variation may be associated with general basil type as the specialty basils ('Cinnamon', 'Kapoor Tulsi', 'Lime' and 'Spicy Globe') all had mean trichome counts that fell between 24 and 31 as compared to the pesto basils 'Amethyst Improved', 'Dolly', 'Eleonora' and 'Napolitano' which fell between 9 and 17. The specialty basils also appear to produce more oil than the pesto basils.



Graph 3. Average number of trichomes observed on the abaxial surface of basil leaves. Error bars are standard deviations used show the range in the number counted on the leaf surface.

Beneficiaries

The immediate beneficiary was the local basil grower, Leafy Greens (Waterloo, Nebraska) who has now given up the idea of using his damaged or excess basil for oil. Given the hits on the website (see below), we feel we have reached the public and hopefully the Buy Fresh Buy Local supporters (~280), Community Crops producers and supporters (~900 community gardens plus 408 donors). We consistently had 173-193 hits each year on the website. Of those 110-133 each year were new viewers. Of note is that the most views occurred in the summer when basil is in the garden and when we always posted new information.

Dates	Page	Keyword	Pageviews	Unique Pageviews	Average time on Page (seconds)
1/01/2016-6/30/2016	Medicinal –and-culinary herbs	not provided	38	29	189
		not set	26	17	101
07/01/2016-9/30/16	Medicinal –and-culinary herbs	not provided	48	38	66
		not set	31	17	155
10/01/16-12/31/16	Medicinal –and-culinary herbs	not provided	50	32	140.09

		not set	24	16	171.25
01/01/2017-03/31/2017	Medicinal –and-culinary herbs	not provided	42	39	91.83
		not set	19	16	73.27
04/01/2017-06/30/2017	Medicinal –and-culinary herbs	not provided	33	25	120.00
		not set	8	4	247.83
07/01/2017-9/30/2017	Medicinal –and-culinary herbs	not provided	45	42	60.94
		not set	12	11	118.67
10/1/2017-12/31/2017	Medicinal –and-culinary herbs	not provided	18	16	55
		not set	17	12	209
01/01/2018-03/31/2018	Medicinal –and-culinary herbs	not provided	43	17	140
		not set	17	11	54
04/01/2018-06/30/2018	Medicinal –and-culinary herbs	not provided	44	36	39
		not set	7	7	170
07/01/2018-9/30/2018	Medicinal –and-culinary herbs	not provided	25	15	48
		not set	20	17	153

Lessons Learned

As a result of the funding for this project, six undergraduate students (3 men and 3 women) learned how to grow basil and manage it until harvest. When asked, the three women (STEM impact) indicated that this experience was pivotal in their post-graduation plans. Two are in graduate school (1 a PhD program) and 1 is working as a research technologist at GeneSeek. The 3 men also said they had a great experience and upon graduation obtained jobs working in horticulture.

The commercial seeds that we obtained of 'Holy' basil were not the same as the variety grown for medicinal purposes. We discovered this when some of our Indian students requested we let them have the extra leaves from plants not used in the greenhouse study. Without a guaranteed source of the proper basil (the commercial companies have since removed it from their inventory), we abandoned using this variety in further tissue culture and greenhouse experiments.

Lastly, you cannot believe everything you read in the international literature. We had a number of stumbles based on other scientists' research (amount of herbage for distillation, method of distillation, etc.). As a result, I feel we were 1 year short of discovering the maximum amount of oil that could be obtained from these cultivars as when we harvested them initially we did not focus on pushing them to flower.

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Presentations: The Healing Power of Plants –general public audience - 53 people each received a cutting with small pot and mix of a medicinal plant - February 22, 2017.
https://news.unl.edu/newsrooms/today/article/scipop-talk-explores-the-healing-power-of-plants/
Symposium Proceedings Articles (Published)

Meyer, G.E., M.E. Conley and E.T. Paparozzi. 2017. Management and Modeling of Winter-time Basil Cultivars Grown with a Cap MAT System. ASABE Paper Number 1701398. 21 pages. The American Society of Agricultural and Biological Engineering, St Joseph MI.
Presentations (Papers)

Wu, Q., W.W. Stroup and E. T. Paparozzi. 2018. Applications of Generalized Additive Models on Extreme Time-Series Sensor Data in Horticulture. 30th Annual Conference on Applied Statistics in Agriculture. **45 statisticians from land grant and other universities in attendance.
Poster Presentation: Hansen, G., T. Dorn, M. E. Conley and E. T. Paparozzi. 2017. Is trichome presence and oil content linked in *Ocimum* (basil) cultivars*?* HortScience 52 (9): S (Abstr.). ** 900 horticulturists in attendance at this national meeting approximately 200 viewed this poster.

Osborn, C., M. E. Conley, W. Wei and E. T. Paparozzi. 2016. Winter production of basil for fresh market and essential oil production. HortScience 51(9): S345 (Abstr.) ** 945 horticulturists in attendance at this national meeting approximately 230 viewed this poster.

Butterfield, A., W. Wei, M. E Conley and E. T. Paparozzi. 2015. Winter production of basil (*Ocimum spp.*) for essential oils. HortScience 50(9): S265. (Abstr.) ** 1025 horticulturists in attendance at this national meeting approximately 450 viewed this poster.

Journal Article: Paparozzi, E. T., W. Wei, M. E. Conley and G. E. Meyer. 2019. Winter production of basil for fresh market and medicinal use. HortScience (in preparation)

Project Title

Healthy Tigers at the Table

Project Summary

This project is designed to provide a tastier, more nutritious food service product through farm-to-school sourcing. We will support the substantial number of local specialty crop producers we have within our region to bring their products into the cafeteria. We will make use of a newly constructed greenhouse to create in-house, local, specialty crop production under the custodianship of East Butler students and staff. Finally, we will foster a collaborative relationship between our food service department and our award-winning agricultural curriculum. We have been very satisfied with our progress thus far. Our first goal was to increase locally produced specialty crop products used in our cafeteria. In the first year of the project, our head chef, Kathy Pelan, ordered fresh produce twice a week from Pekarek's Produce, August through September. After September, our orders decreased to once a week until the producer's supply was exhausted in December. Kathy also ordered cherry tomatoes from Fox Farms each week for six weeks. Combined with our orders from Wahoo Locker and Jisa Farmstead Cheese, we placed approximately 60 orders with local providers.

Project Approach

In conjunction with the goal above, we wanted our food service staff to gain the knowledge of how to use and prepare local products effectively. Under Kathy's direction, the chefs implemented 4 new recipes that incorporated the use of fresh produce. In collaboration with the Center for Rural Affairs, East Butler also hosted a training for food service personal on February 6, 2016, which all kitchen staff attended. To increase awareness of the contributions of local producers, we posted signage by our office and in our cafeteria highlighting the products and the producers every time we served their products. In addition to fostering the partnerships with local producers, we also set a goal of using our greenhouse to supply our cafeteria with produce grown by our students. Under the direction of Shane Hennessy, our Agribusiness instructor, we have featured food from the greenhouse in our cafeteria approximately 20 times. When we do so, we also post signage drawing attention to the food and its source. Regarding integrating farm-to- school in our curriculum, we have had great success in our 5th and 6th grade classrooms both bringing local producers, such as local honey producers, into our classrooms as well as taking part in field trips to see these producers on site (i.e. local dairy farm). Our teachers, Kathy Bohac and Patti Romshek, have been nationally recognized for integrating agriculture into their classrooms.

Goals and Outcomes Achieved

Goal	Performance Measures	Benchmark	Target	Outcome
Locally produced specialty crop products used in cafeteria	frequency of local purchasing	40 purchases	Biweekly purchases in season; purchases throughout off season as available	Biweekly purchase were made with expenditures of $8840.90 over the 2015-2016 school year to present.
Food service staff able to use local products	Staff knowledge about/comfort in using local items	5 new recipes	Staff feels comfortable using local products	Staff made weekly use of local produce and added 6 new

				recipes.
Students and staff aware of local products in cafeteria	Amount of signage Number of farmer visits Self-reported awareness	None None No baseline available	Signage for every local product Monthly farmer visits in growing season All students and staff aware of local products	Signage was posted for all local products we used in multiple locations in the school as well as featured though the school's social media channels.
Greenhouse is a source of cafeteria food	Amount of greenhouse food used in cafeteria	None	Monthly cafeteria use in season	The green house produced less food than anticipated. However, all food produced in the greenhouse made it to our cafeteria every other month.
Integrate farm to school into curriculum	Number of classroom lessons Student knowledge about food topics	4 None	4 local food lessons added to curriculum Students increase knowledge about local food	In our fourth and fifth grade classes 4 local food lessons were added per school year with that content being consistently integrated in to year-long teaching.
Engage community and promote farm to school activities	Number of student events Attendance at community event Media/newsletter coverage	2 20 invitees None	Hold 2 student events 10 families and 10 farmers attend event Monthly coverage in media, school newsletter, and/or CFRA newsletter	In conjunction with our lunch service we held 2 event in which community members and local producers were invited to attend, enjoy our local produce lunch service, and learn from our students as they presented on our ag driven classroom lessons.

Beneficiaries

The project impacted the lunch service of over 270 students on a year basis though enhanced student lunch options and gained awareness of healthy eating habits as well as awareness of the contribution of local producers. Additionally it impacted approximately 30 students on a yearly basis through the curricular instruction focused on the value and actual practice of locally sourced produce. This included the practical application of our greenhouse facilities and agriculture curriculum by students to supply food to our lunch program.

Lastly every dollar spent on locally sourced produces had a positive impact on our local economy and supported sustainability of those producers.

This program has enhanced the collaboration between our local producers and our school community. It has raised awareness of the benefits of consuming form local producers. As to it's economic impact, we do not have a metric to measure this beyond our own expenditures.

Lessons Learned

We are not yet equipped to yield substantial production from our greenhouse to supply our kitchen staff. That being said the novelty of a student produced crop being available truly increases awareness of the benefits of local producers, understanding on the part of all stakeholders the process/benefits/challenges of the farm to table outcome. A follow up which would be interesting would be to ask students how this has influenced how they see their role in agricultural production in the future.

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Project Title

Increased Farm-to-School Specialty Crop Sourcing Through Training, Networking, and Promotion

Project Summary

- What is the specific issue, problem or need that the project will address?

Farm to school programs help farmers address the problem of uncertain demand. Recent focus groups of Nebraska's fruit and vegetable growers (held by project partners) identified that uncertainty regarding when/if to scale up production was a barrier for reaching new markets. Farm to School allows farmers to overcome this barrier. Because schools have to plan for and set their menu plans well in advance of needing the food, they have predictable demand. Since schools operate under contracts for food purchasing, specialty crop farmers know how much and when product will be needed, allowing them to better plan, plant, and grow to meet this need, which in turn improves stability in their operations.

This project enhances the competitiveness of Nebraska's specialty crops growers by expanding an underutilized market, or in many cases, opening a currently untapped new market. Schools are reliable large purchasers of specialty crops, and by tapping into this market, specialty crop farmers can benefit greatly. Furthermore, students who try fresh local fruits and vegetables at school often go home asking for the same products at their families' dinner tables.

National Farm to School Network's research in 2010 indicated that the choice of healthier options in the cafeteria through Farm to School meals resulted in consumption of more fruits and vegetables with an average increase of 0.99 to 1.3 servings per day, including an increase at home. The more schools we can engage in farm to school sourcing, the more we will expand the market for local specialty crop products through school and family purchasing.

In order for farmers to access schools' predictable demand, they need to be able to make sourcing connections with schools. But this can be difficult. We have consistently heard from farmers that they do not know how to connect with food service directors, and from food service directors that they do not know how to find farmers. This project addresses this barrier through farmer/school networking sessions in between trainings for the individual groups.

For farm to school sourcing to work, both farms and schools have to learn how to work in new ways. Farmers must learn how to work with schools, which involves addressing food safety, navigating school order cycles and payment methods, and packaging product in ways that schools can use it. Our farmer training will address these issues. From the school side, schools must learn how to incorporate new fresh items into their menus. Our school food service training will address fresh food recipes, seasonality, preparation and storage techniques and other topics, removing barriers to fresh specialty crop use.

This project also addresses the critical issue of health and wellbeing of Nebraskan children. In Nebraska, more than one in five children (21 percent) are food insecure, meaning that they don't always know where their next meal will come from. Without access to healthy, nutrient-dense fresh foods, families turn to cheaper, "stretchable," easy access processed foods. This leads to critical health issues for Nebraskans. 13.8 percent of children, ages 10-17, in Nebraska are obese, and the problems don't end in childhood. 29.6 percent of adults are obese, 9.2 percent have diabetes, and 30.3 percent have hypertension statewide. Farm to school programs provide a tremendous opportunity to make a significant and sustainable difference in reaching children with healthy, fresh, affordable food. Over 40 percent of Nebraska's schoolchildren receive free or reduced-cost school lunches and breakfasts, and

even more purchase their meals, meaning that school meals provide a large (if not majority) portion of daily food intake for many Nebraskan children. Connecting farmers and schools to source fresh, nutrient-dense, local foods in school lunches gets kids the nutrition they need to learn, grow, and succeed.

- Why is the project important and timely?

Farm to school programs are relatively new to Nebraska. In 2012, when CFRA began working on these projects, there were only four recognized farm to school programs in the state. CFRA and other partner organizations have worked on several projects to facilitate individual farm to school programs, make connections between stakeholders, and raise statewide awareness of and interest in farm to school.

Rising attendance at farm to school programs and conferences, and the more-than-tripled inquiries into farm to school programs, demonstrate interest in these programs is rapidly growing in Nebraska. Funding for this proposal will allow us to reach a wider audience of specialty crop farmers and schools personnel with critical training and support that will lead to farm to school program expansion.

This project was not built on a previously funded project with the SCBGP or SCBGP-FB.

The goals of this project were to:

1. Increase school purchasing and use of fresh specialty crops items from local farmers;

2. Raise the profile of and interest in farm to school programs in Nebraska; and

3. Collaborate with the Nebraska Department of Education on a Harvest of the Month program.

Project Approach

To address the first goal, we trained school food service personnel and farmers through in-person training sessions and webinars, and we directly facilitated connections to improve sourcing between farmers and schools. We expected to reach school participants and farmers with in-person training and webinars. We believed this would result in improving the connection between farmers and school food service personnel.

To address the second goal, we executed a statewide media campaign through news stories and organizational publications, including the Nebraska Center for Rural Affairs (CRFA) farm to school web pages (http://www.cfra.org/farm-to-school). This project built on the expertise and resources of UNL Nutrition and Health Sciences and CFRA's experience facilitating farm to school programs statewide via networking and training.

In 2018, the funds remaining from this grant were used to collaborate with the Nebraska Department of Education on a Harvest of the Month (HOM) program. Nebraska lags behind the nation in incorporating local foods into the cafeteria and classroom. In 2010, only 8% of 9^{th} – 12^{th} graders in Nebraska consumed the recommended servings of fruits and vegetables per day. The HOM program was designed to increase the consumption of fruits and vegetables. The long-term goal of the HOM program is to impact food choices at home, by surrounding youth with nutritional experiences. It is designed to get youth excited about eating fruits and vegetables. Through a short presentation and produce

sampling, youth learned about the importance of eating fruits and vegetables as part of a healthy daily diet.

Goals and Outcomes Achieved

We followed the training and networking sessions with video conferences for farmers and food service workers. We held 2 video conferences that have been viewed by 35 farmers and school foodservice workers. Video conferences covered the topics of “Farming, Schools and Lunch – How to Get it on Your Plate” and “Local Food Procurement”.

We held four training and networking sessions:

- East Butler Public Schools (Brainard), February 6, 2016; 20 attended
- Wayne Public Schools, March 19, 2016; 65 attended
- North Platte Public Schools, April 2, 2016; 24 attended
- Nebraska School Nutrition Association Conference, Kearney, June 27, 2016; 55 attended

All trainings began with an introduction to farm to school, taken from a Nebraska and national perspective, with school food service and farmers participating together. Participants were able to gain a firm and consistent understanding of the topic before breaking out into subgroups of school food service and farmer.

The school food service attendees, led by UNL Extension, were then guided through hands-on cooking and prepping demonstrations with fresh, specialty crop items. Roasted trays of potatoes, beets, turnips, and grapes were served steaming for taste testing. Spears of kohlrabi and carrots, perfect cherry tomatoes, were ready to dip into freshly blended hummus. Watermelon cake (all fruit and no baking!), chili, and many other recipes rolled from cafeteria to palettes for voting on overall flavor and kid friendliness. A variety of skills were addressed, like knife skills, storing fresh produce, and expanding recipe and preparation skills to increase local produce use.

The group also practiced marketing and promoting a local menu by making posters, developing creative names for menu items, and brainstorming ways to bring awareness to the students about the local items, like morning announcements over the loud speaker. The group began to consider how they could take their existing menus and begin to replace or add local specialty crop items.

The farmer breakout session, led by the Center for Rural Affairs, focused on the logistics of communicating with, planning for, and meeting the needs of a school food service department. Discussions were had on pack sizes and types, sharing a product and price list, and taking steps toward farm food safety plans. Also addressed were varieties, size and quality of products that might work for a school, and how to market what products are and could be available.

The networking session followed the breakouts. This was an opportunity for farmers to describe their operations, products, and planning processes for planting and harvesting of products. Some specialty crop producers mentioned they had previously scaled up operations to meet a school’s needs; others had planted special varieties of squash that work better for labor needs at the schools. Still others suggested that selling a bumper crop at the end of the season makes for less waste and greater market potential. All of these farmers were willing to plan in advance with schools for products that the schools might be interested in the coming school year.

As a result of this project, foodservice workers are aware of local produce availability, especially during the school year. The food service manager at a parochial school in Seward said she is, “Aware now

how prevalent local producers are and that this should be something we can do." And the day overall was considered "the most worthwhile day spent learning, ever!"

We expected to reach 40 school participants and 20 farmers in a total of six trainings. In four trainings, we reached 155 school participants and 9 farmers. We have well exceeded our expected school participant reach, and slightly lagged behind with our farmer participation.

The support of the Nebraska School Nutrition Association (NSNA) became a key factor in the high rate of school participation. When NSNA became aware of the trainings, they requested that we schedule our training when NSNA districts would be convening for district meetings in their regions. This led to greater buy-in from NSNA as a whole and to efficient promotion of the trainings.

There are indications of increased farm to school interest at the school level. Several districts that were not able to host one of our trainings focused on farm-to-school at their fall district meetings. And because District 6 in northern Nebraska met Robert Bernt of Clear Creek Organic Farm in Spalding at our Wayne training, they planned a farm tour with Robert for August. The tour was a huge success and you can read more about it at http://www.cfra.org/news/161014/real-deal-farm-school-nebraska-farm.

There also was a great deal of support from the host schools. They provided lunch for the training and built a menu around foods that could be sourced locally and served in schools. They also offered their kitchens for the trainers to cook for food demonstrations.

In order to promote the trainings, we did media releases for each training, flyers to distribute via listservs and at conferences and gatherings, featured the trainings on CFRA's website and newsletters (http://www.cfra.org/news/160720/hilda-considers-farm-to-school; http://www.cfra.org/news/160418/schools-and-farms-build-local-fruit-and-vegetable-market). Success was shared on social media outlets including Facebook, Instagram and Twitter. These trainings were also shared on CFRA's website and broadcasted monthly on the Nebraska Farm-to-School e-newsletter, which consists of 500 subscribers.

Farm-to-school is becoming more known statewide. We receive inquiries weekly from schools wanting to know how to get started. Our farm-to-school page had 2,927 page views. Our farm-to-school guidebook had 845 page views, and our "Find a Farmer Map" had 314 page views. There were 248 media clips reported from CFRA's farm-to-school work.

In 2018, it was decided that the remaining funds be used to work with the HOM program. This is a joint program between Nebraska Cooperative Development Center and Nebraska Extension. Funds were used to help youth develop food preparation skills. Each month, youth learned about a produce item grown in Nebraska. Lessons were developed to teach growing, nutrition, and produce preparation. The HOM program is an opportunity to celebrate local foods and try new recipes. The goal is to encourage healthy food choices by increasing students' exposure to seasonal foods. Six schools agreed to pilot the HOM program.

Nebraska Extension and Nebraska Department of Education are collaborating to develop a toolkit titled "Harvest of the Month: Farm-to-School Project." Resources include HOM logos, posters, recipes (for home and school), newsletter, and a "Taste Test Guide." These resources will be used in Nebraska schools in an effort to increase the consumption of specialty crops.

Beneficiaries

The beneficiaries of this project include 155 school participants and 9 farmers. It also includes the 6 school who agreed to pilot the HOM program. Youth are also the beneficiaries of this project by having access to fresh produce. They were exposed to foods, such as, turnips, collards, Great Northern beans and sweet potatoes. Parents will receive a newsletter containing nutrition information, fun facts and a recipe they may want to try at home. Farmers have also benefited by identifying more outlets for their specialty crops.

Lessons Learned

We were not able to schedule all six trainings as originally planned.

Trainers, host sites and potentially conflicting local events all needed to be considered and required us to be more flexible with our dates. Therefore, four of our trainings were completed. We also needed more lead time for planning and promoting.

Due to the delay of the in-person trainings, we also delayed the farmer and school food service webinars. We host those in January (producer) and February (school food service). This timing works well with farmer and school schedules.

While we have far exceeded our school food service attendee numbers at the trainings, we have not had the same experience with farmers. We expected 20 specialty crop farmers would attend in-person training sessions. With four training sessions complete, we only had 9 farmers who attended.

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Project Title

Extension Education and Food/Safety and Security Coordination

Project Summary

South Sioux City has a diverse population. With most of our citizens falling in the low-to-moderate income range, this grant has allowed us to teach many gardeners about growing crops they do not normally grow. The grant has allowed us the opportunity to not only teach adults about growing, harvesting and storing produce safely, but also to begin teaching youth these same concepts. Many people in the community had expressed an interest in gardening, but did not have the knowledge to gardening, understand the climate and diversity of crops, or the space to be successful gardeners. The city of South Sioux City added space to allow the citizens to garden. This grant builds on that foundation.

Project Approach

Our goal is to improve the lives of the citizens of South Sioux City and the surrounding area. The approach with this grant was to encourage those who have limited resources to eat healthy by learning to successfully grow their own food safely. We accomplished that by impacting over 50 families in a 3 year time span through numerous educational classes and hands-on training giving them the ability to succeed in crop production. Yearly, we recruited new participants from the community and encouraged past participants to continue. We directly taught gardeners and also our community garden manager, who is now teaching all the participants. We were successful in teaching our gardeners how to plant, cultivate and harvest 20 different crops. All participants learned many aspects of growing food including composting, soil amendments, and the role pollinators have in crop production.

Goals and Outcomes Achieved

Goal #1: Recruit 10 or more new socially disadvantaged farmers in the community.

In addition to the existing participants (33) at the two locations the city has for beginning farmers and gardeners, the program saw 11 new beginning farmers, gardeners join the program in 2017.

We had 22 families participate in this grant in 2018. Six of the families were new to the program this year. Those families are from El Salvador, Guatemala, Mexico, Kenya and the United States.

In 2018, we helped families who participated in the past graduate from the community garden and begin gardening at their homes. We continue to encourage them to ask for advice and participate in our classes. Of the gardeners that graduated, we believe that over 15 are now gardening at home. Many of the others have continued gardening at the community garden or have moved and are currently not participating.

Our successful advertising was through the South Sioux City Library, the city newsletter and word of mouth.

Goal #2: Teach food safety methods specific to planting, handling, harvesting, storing, canning, freezing and cooking the diverse varieties of specialty crops grown by a minimum of the 10 socially disadvantaged farmers and those seeking to expand their current farming operations.

Our gardeners enjoyed learning about bees and the role they play in the success of food production. We held a class on native bees and had participants make a solitary bee hotel to use near their own gardens. We also worked to teach participants about honey bees producing honey as a specialty crop and their importance as pollinators for all food production.

The hives at the community orchard were successful in spinning honey from the comb. There was an Introduction to Beekeeping class offered on December 10, 2016 taught by Judy Wu- Smart and there were 26 participants. Interestingly enough, of the 26 participants, 8 of them had pre-registered and had their fees paid for. The additional 18 participants who showed up willingly paid their own fees and the UNL extension sponsored the program speaker. Additionally, there were several times throughout the year when several interested participants came out to observe the Iowa bee inspector when he came over for an inspection, along with several meetings with the NW Iowa Bee Keeping group. This appears to be a program area that is generating an increased interest and is growing in individuals interested in participating.

In addition to programs with the bees, on May 12, 2017 a food safety class was held that had 10 participants register and attend. There weren't near the number of classes held during the winter months as planned for so the program was not able to offer the tours, conferences as it had intended the previous year.

During the 3rd year of the grant, two food safety/preservation classes were held. A hands-on class provided participants the basics of canning tomatoes. The other was an overview of how to safely preserve garden produce. Both classes learned about canning, freezing and drying. The classes were applicable for what they were growing in their gardens. Also, information was provided on what they could sell at a farmers market. There were a total of 17 participants for the 2 classes. About half the participants said they never checked home preserved food for spoilage. However, all said they would check food for spoilage after taking the class. Participants learned what types of spoilage organisms are usually found in jams and jellies and in items that need to be pressure canned. Three participants who had tried canning before said they had not used up-to-date information on proper canning, but would now use the current recommendations for canning. Evaluations included asking them what they knew before the class and what they learned from taking the class.

Garden Show Classes

We encouraged participants to attend the Siouxland Garden Show, April 2018, in Sioux City, Iowa. Three gardeners participated in the classes. There were 24 gardening classes offered. Of interest to our project included a talk on Donation Gardening by Christine Hradek, Iowa State University Extension and Outreach coordinator of the *Buy. Eat. Live Healthy* program. This program is designed for families experiencing poverty. Other classes we encouraged them to participate in were Food Preservation; Garlics; Onions and Leeks; Organic Gardening; Seeds; Raised Beds; Cooking with Fruit; Cooking with Vegetables; Small Fruits; and New Varieties of Annuals, Vegetables and Perennials.

School Gardening

We extended some basic gardening lessons to the South Sioux City Cardinal Elementary After School program. Over 70% of the students in the South Sioux City school district receive free or reduced lunches. We saw this as another avenue to help the community understand how small scale farming, with specialty crops, can benefit families. During the spring of 2018, 32 students met 8 times with 2 lessons each time on gardening, nutrition, and growing and eating local. During summer school, we met with 43 students for 10 lessons on the same topics. Students had the opportunity to try a variety of fruits and vegetables and participate in planning and planting a small garden. When school started again in the fall, students were able to taste vegetables they had planted along with other fruits and vegetables from gardens in the community.

Library Classes
Eleven classes were offered on basic gardening over 3 months in the winter. Most of the classes were taught by a UNL Master Gardener and guest speakers including Keith Jarvi, a retired UNL entomologist. Classes had between 3 and 11 participants. Translation services were offered.

Education was provided to socially disadvantaged farmers about the role they can play in alleviating the food security issues that exist within the community through the adoption of the “Add a Row” concept.

Goal #3: Diversify the types of specialty crops grown was specific to those that are essential to food security.

In 2017, there were new participants from India, Guatemala, El Salvador, Kenya and Mexico. Those participants grew the following crops and donated them as part of the “Add A Row” program to the local pantry. The following is a list of the crop grown and the pounds for each crop donated to the local pantry:

Red Beans – 29.75lbs
Cucumbers – 42lbs
Banana Peppers – 8lbs
Zucchini – 74.5lbs
Bell Peppers – 21.75lbs
Butternut Squash – 28lbs
Cilantro – 6lbs
Total pounds donated = 210 lbs
Food that did not produce this year – Jicama

Tour a Successful Garden
We were able to take eight of our gardeners to tour the *Voices for Food Community Learning Garden*. This garden grew 9,000 pounds of food that was donated to the area pantry system in 2018. The Master Gardener who oversees this garden, talked to them about how she is able to grow so much food. They picked up pointers from her on growing techniques for a variety of produce. The gardeners used produce for their own use, but shared over 175 pounds with local families in need. Below is a list of crops planted in 2018 by the participants.

Tennessee Red Peanut
Bean, Cherokee Trail of Tears
Bean, Lina Sisco's Bird Egg
Soybean, Agate
Squash, Winter Luxury
Butternut Rogosa Violina "Gioia" Squash
Orangeglo Watermelon
Long Island Cheese Pumpkin
Thai Red Chili Pepper
Tennis Ball Lettuce
Carentan Leek
Ronde De Nice Summer Squash
Rainbow Mix Beet Seeds
Rainbow Blend Carrot Seeds
American Purple Top Rutabaga Seeds
All-American Parsnip Seeds

Pak Choy White Stem Chinese Cabbage Seeds
Purple Vienna Kohlrabi Seeds
Red Burgundy Okra Seeds
Rainbow of Lights Swiss Chard Seeds

Gardeners planted seeds from their country of origin. They collaborated with other gardeners about the plants from their country and how they used these plants for food in their native country. These included the following:

Tomatillo del diablo – from Central America, fruit is black when ripe
Beans, Chisaga, Egesare - from Kenya, harvested to eat the leaves.

One of the critical items needed at the orchard location was an Orchard Learning Center. Throughout the fall, a group of UNL students worked to develop a design that would create a functional storage shed for use by program participants and volunteers. The facility has been built. The significance behind this multi-purpose facility is to store equipment and have a gathering place for program participants to meet and conduct hands-on activities without having to compete for space in areas such as libraries, community rooms, and extension offices.

Beneficiaries

Almost 60% of the homes in South Sioux City are rentals. Our population often moves or is gone over the summer to their native country. Over 50% of the participants this year live in an apartment. During this grant, we impacted over 50 families with practical hands-on gardening practices, introduced a number of crops that are unfamiliar to them, and expanded their opportunities for small scale crop production and personal dietary needs.

Our garden manager worked closely with all gardeners individually, encouraging them to attend our classes and learn from her and fellow gardeners. She talked with them several times a week at the beginning of the season and up until harvest. Our best teaching happened when we would teach the manager and she would individually teach the participants in the garden.

Our city benefited in the fact that participants, even though culturally different, become a close knit community as they gardened together, shared expertise, and made new friends. We hope to continue helping socially disadvantaged farmers learn to be productive gardeners.

Lessons Learned

The program saw a large turnover from the year previous year following the results of the Presidential election and the ethnicity of a number of the beginning farmers. Sadly, many relationships were severed due to wariness to be involved in government aided programs and a lack of trust was present with those who had enlisted in the program prior. It wasn't until the end of the 2017 season that the City of South Sioux's seasonal worker, Christina was able to work through and bridge some of the gaps with the newer farmers. As a result, the numbers of activities were not as successful as planned for. The library hosted a number of classes, however, the participants were not willing to sign in, thus making it difficult to accurately capture and record the actual number of attendees with validation by signature.

Problems and delays due to inclement weather throughout the winter months, along with a significant drought during the key growing months plagued the program. Additional problems and delays were met with finding tours and conferences for the participants to attend that allow for limited time away

from work and families. The program was basing the classes and activities during down times in the growing season, but ultimately this is when many of the participants are busy with work and other activities creating conflicts in schedules. Furthermore, many of the participants come from countries where they are not familiar with the inclement weather in the winter and simply do not want to venture out unless it is for vital necessities and to and from work. Knowing this has been helpful in understanding the lack of interest in participation in classes during the winter months when to most it makes logical sense to host them on the weekends outside the growing season. For the first time ever, the feedback received is contraindicated to what one would logically surmise as being an ideal time to host classes. The program participants would rather host classes during weekends when they are at the gardens/small farming plots and orchards as it coincides with the work they are already there for. That is why the storage/educational cabin that were constructed this summer is integral for providing the necessary education that was outlined in the program. Consequently, no pre-test or post tests have been administered to date to measure knowledge gained and learned. However, evidence does exist that the program participants did learn a great deal about the "Add A Row" program and opted to participate as evident by the number of pounds donated to the local food pantry.

An additional challenge that the project faced was the loss of two of the starter bee hives. It is suspected that this may have been insecticide damage as the hives were ok in August, but went down quickly after that. Although the orchard and garden/farming plots utilize natural insecticide methods, there are nearby farms that do not subscribe to the same methodologies and it is suspected that the loss of the two starter hives may have had some sort of connection. Additionally, due to dry weather conditions, the number of insects saw a dramatic rise. The Japanese beetle was especially challenging and a number of insecticides were utilized to attempt to control its population that may have had resulted in ill effects on the starter hives as well.

Our plan to advertise was revised, as flyers did not bring participants to trainings.
We learned that we reach each culture with information in different ways.
Our most successful was word of mouth.

We learned to be mindful of the busy schedules that our participants had, with many of them working long hours or having 2 jobs to make ends meet. We had the most success teaching our gardeners when they were working at their garden plot. Our garden manager would work one-on-one with them in the garden.

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Project Title

Re-Mediation of High Cholesterol and Inflammation by Pinto Beans (Raw and Baked)

Project Summary

Dry edible beans are an important Nebraska specialty crop with our state being the No. 1 and No. 2 U.S. supplier of the great northern beans and pinto beans, respectively. Studies have shown that dry edible beans contain natural antioxidative agents greater than or comparable to many types of fruits, vegetables, and cereals. These natural antioxidative agents. For example, the phenolic compounds, have in turn been linked to multiple health benefits, including cardiovascular health and cancer prevention. The goal of this project was to determine whether pinto beans (uncooked and cooked) were capable of remediating both high cholesterol and intestinal inflammation or stress leading to inflammation, which are common in people who consume high fatty diets composed of high levels of saturated fatty acid, which is particularly common in western societies. The central hypothesis for this research was that it would be able to positively impact both types of health stresses due to the diversity of phenols and the presence of other health promoting components. These health effects would also differ based on the cooking processes used, as the composition of the bean nutrient profile was expected either to be enhanced or compromised. The objectives of this project were to:

1. Characterize uncooked and cooked pinto beans as food systems with dual health targets (e.g., reduced cholesterol and intestinal stress); and

2. Advance the understanding of bean market classes and their health benefits relevant to major national health concerns that are afflicting western societies by disseminating this information to national and international stakeholders.

It should be noted that uncooked pinto beans were selected for this project to serve as a point of reference as we recognize that pinto beans are always cooked prior to consumption. By understanding the health benefiting components present in the raw state that may also be affected by environment, growing location and farming practices, this knowledge is essential to providing feedback to the breeder that enhance the health benefiting properties, It is also designed to ensure food processors to develop cooking operations that do not compromise the health promoting components. As such, this project was expected to provide information that would increase the consumption of pinto beans by western societies, thereby increasing prices and overall demands of dry edible beans produced in Western Nebraska. Also, information would be available to both the bean breeder to produce health promoting beans while disbursing information to the bean food developer to design pinto beans based products that do not compromise the responsible components. The dry edible bean industry is shrinking in multiple regions, many of which are economically suppressed. It is expected that increased demand will provide timely support in these rural areas and the consumption of beans will increase, thereby increasing bean prices.

A significant issue facing the U.S. dry edible bean industry is the current price of competing field crops, such as corn and the influx of dry edible beans from international sources. As a result, the number of acres dedicated to dry edible bean production has been declining in most U.S. states with the largest decreases occurring in Texas, Colorado, and Nebraska. Nebraska regions most affected by this decline include several counties located throughout the state, but particularly those in the Panhandle area. This geographic region has a clear need for higher paying jobs as 100% of these Nebraska counties have a median household income 22% below the state average. Additionally, population growth in these regions has been flat between 2000 and 2016 with the participating counties experiencing at least a 6% population decline. As the number of acres of dry edible bean production declines, so too does their economic viability, which, in turn, adversely affects the rest of the economies in the region. Adding

value to dry edible beans by promoting beans as a healthy dietary food system is expected to increase consumption and stabilize the dry edible bean industry in our state. This project is therefore important as it will be the first to determine the health benefits of pinto beans in response to high cholesterol and intestinal stress induced by western diet (i.e. diets high in saturated fat).

Project Approach

The objective of this proposal was accomplished by completing the specific aims listed below.

Specific Aim 1 (completed and described thoroughly in 1st interim report) was to characterize and compare the components of uncooked and cooked pinto beans. Uncooked and cooked (steamed) pinto beans (LaPaz) grown in Scottsbluff Nebraska, by Dr. Carlos Urrea in 2014 were characterized for protein, moisture, saponins, carbohydrates, fat, fatty acid profiles, dietary fiber, phytic acid, lignin, tannins, raffinose, stachyose, total phenols, total flavonoids, and total condensed tannins. Also, hulls were added to this study due to preliminary data obtained in our laboratory with great northern beans. Study showed a positive cholesterol- lowering effect. Therefore, the hulls were also characterized for the components described above.

Specific Aim 2 (completed and described thoroughly in 1st and 2nd interim reports) was to determine and compare the cholesterol remediation effect of uncooked and cooked pinto beans using a hamster model. Sprague male hamsters were obtained for this study as these animals have similar cholesterol metabolism mechanisms as humans. The general clinical experiment consisted of dividing 66 hamsters into 6 groups (n=11) whereas the experiment for cooked beans consisted of dividing 44 hamsters into 4 groups (n=11). The composition of the diets was included in previous reports. In summary, four types of diets were introduced to the animals:

1. A low fat diet (control);

2. An atherosclerosis (athero) diet induced by coconut oil (a highly saturated oil) and 2% dietary cholesterol;

3. An athero diet supplemented with 5 or 10% whole pinto beans; and

4. An athero diet supplemented with 0.5% or 1% pinto beans hull.

The hull quantity was selected as the hull comprises approximately 10% of the bean, but many of the micronutrients are concentrated in the hull. The decision to adjust to only 5% cooked whole bean and 0.5% cooked hull was based on the amount of beans a person may consume on a daily basis. The lower amount was a more reasonable daily intake for human subjects considering the currently low intake of beans by western societies. Moreover, the results from the uncooked beans showed that 5% whole bean and 0.5% hull were, in most cases, just as effective as positively affecting cholesterol markers as the 10% whole bean and the 0.1% hull.

Each hamster was weighted and then housed in a separate cage and allowed free access to water and food, the latter of which was routinely weighted. Each of the hamster's fecal material was also obtained every two weeks. After four weeks of feeding, the hamsters were weighed again, euthanized, and their plasma, livers and large / small intestines were collected. Plasma markers for cholesterol were measured and consisted of high density lipoprotein cholesterol (HDL), non-HDL cholesterol, (which is a combination of very low density lipoprotein, and low density lipoprotein), and triglycerides (TAGS), (which also play a role in raising cholesterol levels). Liver markers for cholesterol consisted of free

cholesterol, esterified cholesterol, and triglycerides. Lastly, the fecal matter was analyzed for bile acids and neutral sterols. To determine a possible mechanism, liver cholesterol levels were correlated to that excreted into the fecal matter.

Specific Aim 3 (described below) was to determine and compare the intestinal stress (inflammation) remediation by uncooked and cooked pinto beans caused by diets high in saturated fat. After euthanizing the hamsters, the large intestine was extracted from each hamster and flash frozen in liquid nitrogen and stored in a -80°C freezer until analysis. Intermediates of glycolysis, the tricyclic acid cycle metabolites, and amino acids were extracted using methods developed in our lab. The intestine tissue extracts were then tested for metabolomic targeted analysis of central carbohydrate metabolism via HPLC-MS-High performance liquid chromatography-mass spectrometry (LC-MS), Capillary Electrophoresis (CE) and Gas Chromatography (GC).

Goals and Outcomes Achieved

As shown below, uncooked beans were able to remediate the effects of the many metabolites involved in energy pathways. This can have an effect on intestinal stress in terms of hypoxic, which can lead to inflammation, colon cancer, irritable bowel syndrome, and colitis. It must be noted that many energy metabolites were analyzed but their response is not indicated herein because they were not affected by either the high fat diet or the bean supplement high fat diet.

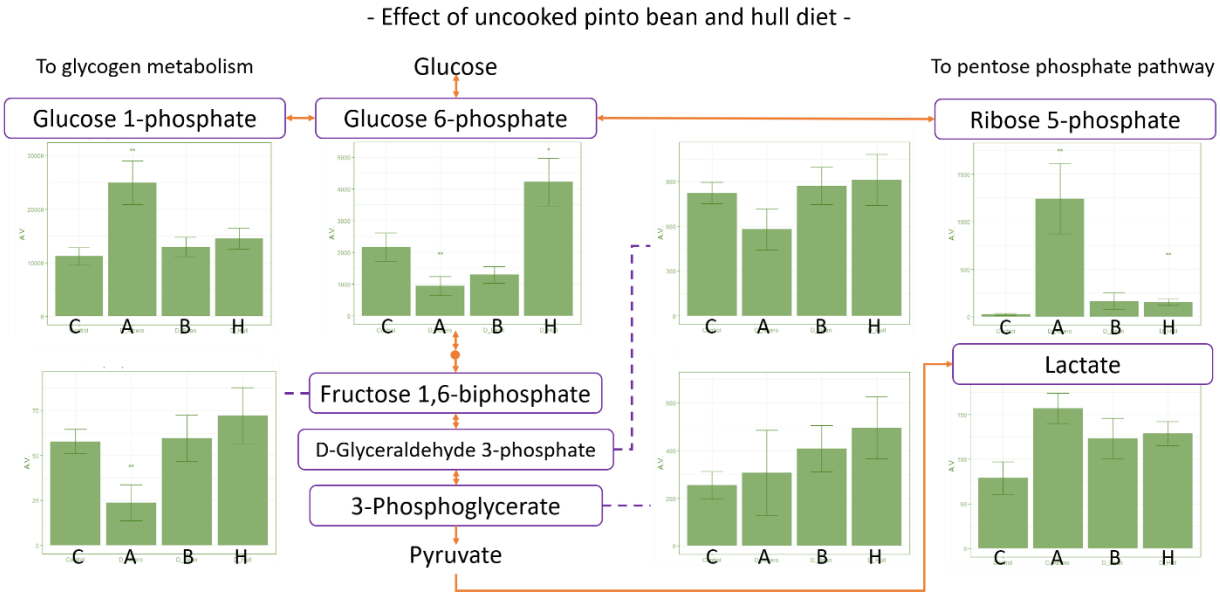

Figure 1 shows the effect of high saturated fat diet with and without **uncooked** pinto bean supplementation on the intestinal glycolysis intermediates and sugar phosphates. C-Control diet, A-Athero diet, B-Athero+Bean diet and H-Athero+Hull diet. Diet high in saturated fat (A) significantly decreased the glucose 6-phosphate, Fructose 1,6-biphosphate and D-glyceraldehyde 3-phosphate level in large intestine indicating an increased glycolysis. High fat diet also resulted in the accumulation of Ribose 5-phosphate indicating a reduced activity in pentose phosphate pathway. In addition, increased level of Glucose 1-phosphate suggests a reduced glycogen metabolism. Including pinto beans and their hulls in the high fat diet (B and H) remediated the effect of high saturated fat as evidence by the increased level of glucose 6-phosphate, Fructose 1,6-biphosphate and D-glyceraldehyde 3-phosphate and decreased level of Ribose 5-phosphate and Glucose 1-phosphate. Finally, elevated lactate level produce by the in high fat diet groups is consistent with results

summarized in recent review by Adeva-Andany, M., et al. (2014). Pinto bean supplements reduced the lactate accumulation.

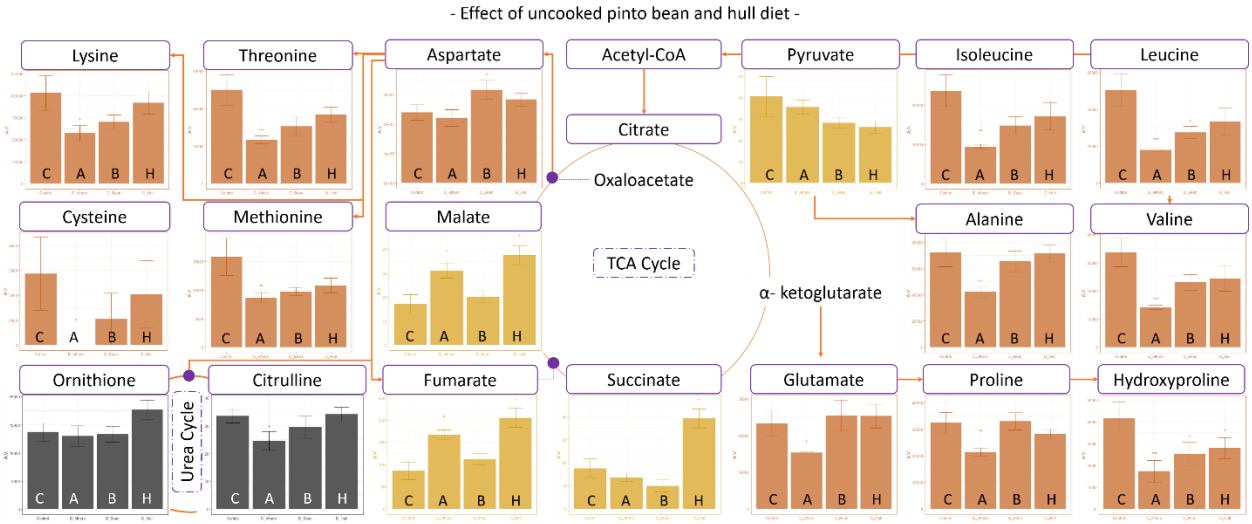

Figure 2 shows the effect of high saturated fat diet with and without **uncooked** pinto bean supplementation on the intestinal TCA cycle intermediates and amino acids metabolism. C-Control diet, A-Athero diet, B-Athero+Bean diet and H-Athero+Hull diet. Accumulation of TCA cycle intermediates Fumarate and Malate caused by the high fat diet inhibiting hypoxia inducible 1 alpha (HIF-1a) hydroxylase, leading to HIF-1a stabilization and potential hypoxic conditions. Supplementing uncooked beans remediated the effect of high fat diet. However, this effect was not present in the hull supplemented diet. The majority of amino acids (hydroxyl proline, alanine, proline, serine, cysteine, threonine, isoleucine, methionine, valine, glycine, tryptophan, glutamate, histidine and lysine) were reduced in the presence of a high fat diet, but restored with the bean and hull supplements. Studies have shown that interference of amino acid metabolism can lead to inflammation as provided in the review by McNally et al. CNS Spectrums, volume 13, 2008, pp 501-510. Although low levels of hydroxyl proline and proline have not been associated to inflammation to our knowledge, supplemented hydroxyl proline and proline are shown to improve tissue related inflammation. In this study, both metabolites were reduced by a HF diet and remediated by the bean supplements (comparable to the control).

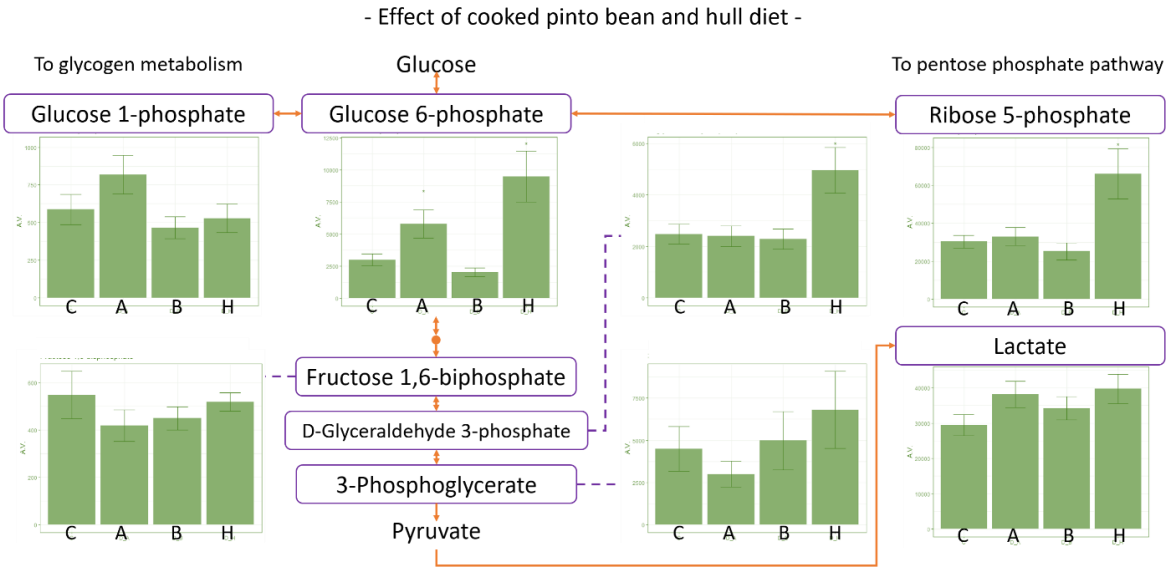

Figure 3 shows the effect of high saturated fat diet with and without **cooked** pinto bean supplementation on the intestinal glycolysis intermediates and sugar phosphates. C-Control diet, A-Athero diet, B-Athero+Bean diet and H-Athero+Hull diet. Diet high in saturated fat (A) decreased Fructose 1,6-biphosphate and 3-Phosphoglycerate level in large intestine indicating an increased glycolysis. Similar to the results of uncooked bean high-fat diet group, increased level of Glucose 1-phosphate suggests a reduced glycogen metabolism and elevated level of lactate suggests a decreased lactate metabolism. Including cooked pinto beans and their hulls in the high fat diet (B and H) remediated the effect of high saturated fat as evidence by the increased level of Fructose 1,6-biphosphate and 3-Phosphoglycerate and decreased level of Glucose 1-phosphate. The results on the profile of Glucose 6-phosphate and D-Glyceraldehyde 3-phosphate are mixed when comparing results from uncooked and cooked beans experiments. It is likely due to the fact that fecal matter was present in some of the large intestine samples and contributed to the variation.

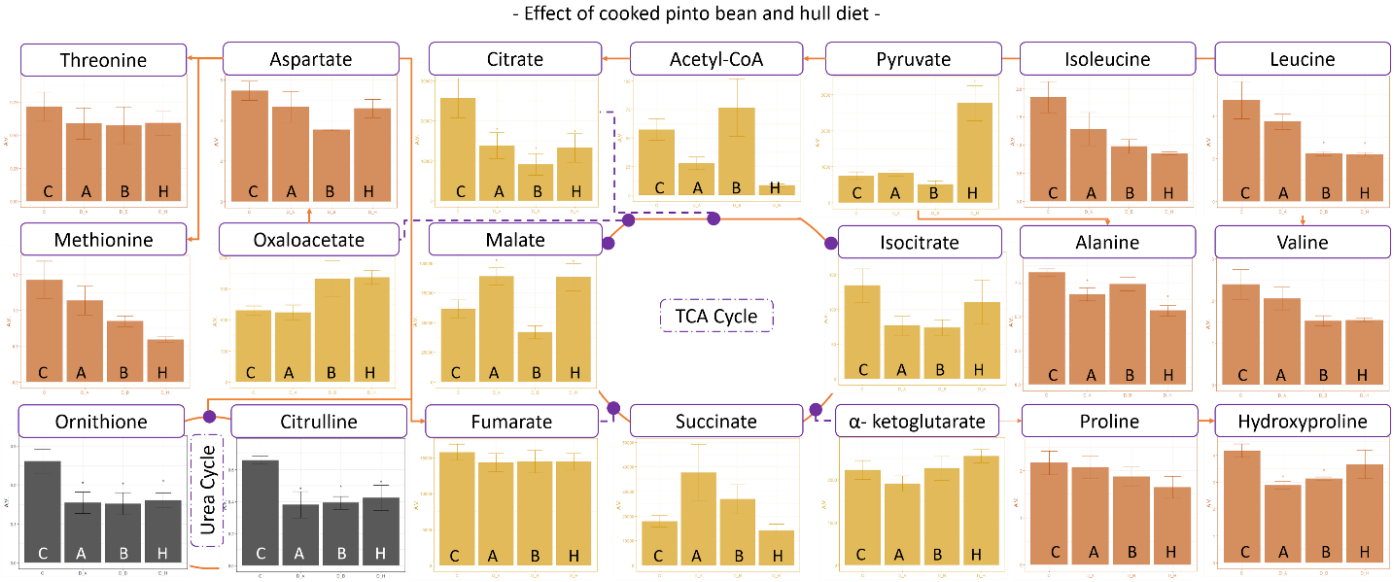

Figure 4 shows the effect of high saturated fat diet with and without **cooked** pinto bean supplementation on the intestinal TCA cycle intermediates and amino acids metabolism. C-Control diet, A-Athero diet, B-Athero+Bean diet and H-Athero+Hull diet. Mass Spec method was used to analyze TCA cycle intermediates and resulted in more metabolites profiled. Diet high in saturated fat (A) significantly reduced Acetyl-CoA, Citrate, Isocitrate and α-Ketoglutarate and increased Succinate and Malate in the TCA cycle. Supplementing cooked pinto beans remediated the effect of high fat diet on Acetyl-CoA, Succinate, α-Ketoglutarate and Malate, whereas cooked pinto bean hulls remediated the effect on Isocitrate, Succinate and α-Ketoglutarate. Similar to the results with the uncooked bean supplement, the majority of amino acids (hydroxyl proline, proline, alanine, threonine, isoleucine, leucine, methionine and valine) were reduced in the presence of a high fat diet. However, cooked bean and hull supplements did not restore all the effect of high fat diet. In addition, reduced level of orthithione and citrulline was detected in the high fat diet group indicating an elevated Urea cycle. The effect was not remediated by the cooked bean and hull supplementations.

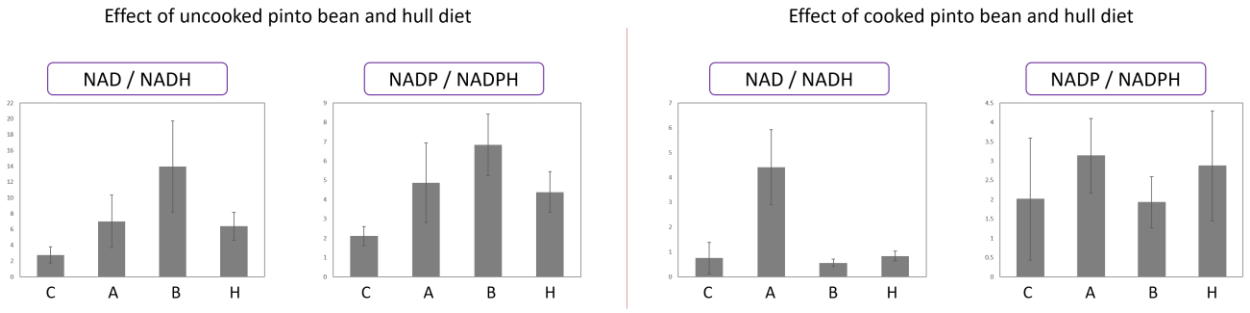

Figure 5 shows the NAD/NADH and NADP/NADPH ratio in the intestine tissues. C-Control diet, A-Athero diet, B-Athero+Bean diet and H-Athero+Hull diet. Due to the unstable nature of the compounds, oxidized form of the nucleotide phosphates were predominately detected. The high saturated fat diet increased the ratio of both NAD/NADH and NADP/NADPH indicating a more oxidized state in the intestine. Supplementing cooked pinto beans remediated the effect on both nucleotide phosphates.

Results are expressed as mean and standard error of the mean (SEM). Student t-test was performed to determine the significant difference between Control diet and High-Fat diets with or without Pinto bean supplements (* $p < 0.05$, ** $p < 0.01$).

Significant results to date include:

1. Pinto beans supplemented into a fatty acid lowers plasma cholesterol similar to that of a low fat diet regardless of the dosage used. Interesting, this benefit could not be due solely to dietary fiber, (as this component is present in the whole bean), because the hulls also lowered plasma cholesterol similar to that of the whole beans. The hulls are now being characterized to identify the possible components. Considering that the hulls are expected to contain many micronutrients, such as the phenols, these results are very intriguing. As such, cooking the pinto beans may degrade these micronutrients, thereby affecting the cholesterol targets. For liver cholesterol, the whole bean and hull dosage did affect the extent of cholesterol present in organ and excreted from the body indicating that pinto beans act cholesterol targets.

2. In the case of the intestinal stress study for uncooked beans, it was clearly shown that the cholesterol induced diet affects glycolysis, the TCA cycle and amino acid metabolism. However, many of the metabolites present in these pathways were not affected when whole beans or hulls were present. Most importantly, amino acid metabolism was lowered by high fat diet, which has been linked to inflammation, but the uncooked bean supplement restored this mechanism.

For the cholesterol studies, it was interesting that favorable results were still achieved with the cooked beans, albeit not to the extent as the uncooked beans. However, it was impressive given the degradation of key components known to lower cholesterol. It was determined that the hulls only composition did add to the lowering effect, and, in most cases, the whole bean had to be consumed to obtain the optimal benefits. Therefore, more research is needed to determine the responsible components. Mechanisms to lower cholesterol changed for the raw versus cooked beans. This could be a starting point for developing / processing health promoting beans.

As for the intestinal studies, it was not determined if inflammation or hypoxia was affected via these studies. However, energy was affected, which can lead to stress. This outcome shows that health can be maintained before harmful stresses lead to disease. Prevention of eating a saturated fatty diet can prove to be beneficial. The studies showed that the hull and whole bean produced different results as

did the raw versus cooked beans. With more studies, these advantages or disadvantages can be resolved with the breeder, food biochemist, and food developer working together.

Beneficiaries

During the short term, no other group will be benefitting by this research, as it is still in its basic format. That being said, if research is allowed to continue, we expect that producers will earn more income from pinto beans by establishing this food as a functional food, which is sold at much higher costs than other conventional foods. Production, and thus the producers' load, will go down, which in turn will enable the land to rest maintain a healthy farm. Also, distributors will be positively affected as will the health of our citizens.

The cholesterol data from the first study (uncooked beans) was submitted for publication in the Nebraska / Wyoming farmers' newsletter "Bean Bag" with publication in the Fall of 2018. Two-three papers from the intestinal studies are currently being prepared, two others from the cholesterol studies have been composed with one submitted for publication, but notification is pending. (The other two will be submitted sequentially as to tell the full story). A graduate student completed his PhD. on the cholesterol work. A Facebook page focused on "UNL Beans for Health" is under consideration. The cholesterol research was also reported internally and externally through local outlets at UNL and local television programs.

Lessons Learned

The most important factor that was learned from this project was the mechanism change linked to the benefits based on cooked versus uncooked and the contribution of the hulls. Therefore, subsequent experiments would include the bean without the hull as part of the diet.

Energy stress was positively affected from consumption of beans when used as a supplement in a fat saturated diet, which is more beneficial than affecting inflammation or hypoxia, which probably would happen as well. However, energy is the key to preventing multiple stresses that lead to disease.

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Additional Information

Table 1: Composition of uncooked Pinto beans (LaPaz)

Composition	Pinto bean (LaPaz)	Pinto bean hull
Crude protein (%)	20.84 +/- 0.34a	14.6 +/- 0.02b
Carbohydrates (%)	63.69 +/- 0.34a	65.77 +/- 0.23a
Crude lipid (%)	1.23 +/- 0.00a	1.08 +/- 0.08b
Moisture content (%)	10.00 +/- 0.01a	13.42 +/- 0.10b
Ash (%)	4.24 +/- 0.01a	5.13 +/- 0.04b

Dietary fiber (mg/g)	220.83 +/- 20.50a	374.13 +/- 40.02b
Total phenolic content (mg GAE/g)	5.77 +/- 0.93a	31.52 +/- 0.75b
Total flavonoids (mg CE/g)	6.09 +/- 0.08a	58.63 +/- 1.02b
Total condensed tannins (mg CE/g)	21.59 +/- 0.15a	99.04 +/- 0.12b
Total saponins (mg Aescin/g)	39.85 +/- 0.91a	221.71 +/- 3.67b
Phytic acids (mg/g)	19.01 +/- 0.96a	14.36 +/- 0.45b
Lignin (mg/g)	83.24 +/- 13.2	
Oligosaccharides Raffinose (mg/g) Stachyose (mg/g)	 11.19 +/- 0.62 39.72 +/- 4.23	
Fatty acid compositions (% of total FA) Palmitic Stearic Oleic Linoleic Linolenic	 23.46 +/- 0.79 1.80 +/- 0.06 8.23 +/- 0.11 35.67 +/- 0.10 30.84 +/- 0.86	

Table 2: Composition of cooked bean based diets fed to hamsters

Food Component	**Control**	**Athero**	**Athero + 5% Whole Pinto Bean**	**Athero + 0.5% Hull Pinto Bean**
g/kg of diet				
Corn Starch	455.7	353.7	313.7	348.7
Dextrinized cornstarch	155	155	155	155
Casein	140	140	130	140
Sucrose	100	100	100	100
Coconut oil	---	100	---	100
Soybean oil	50	50	50	50
Insoluble fiber (cellulose)	40	40	40	40
Soluble fiber (guar gum)	10	10	10	10
Pinto bean (whole bean)	---	----	50	---
Pinto bean (hull)	---	----	---	5
Cholesterol	---	2	2	2
AIN-93 mineral mix	35	35	35	35
AIN-93 vitamin mix	10	10	10	10
L-Cystine	1.8	1.8	1.8	1.8
Choline bitartrate	2.5	2.5	2.5	2.5

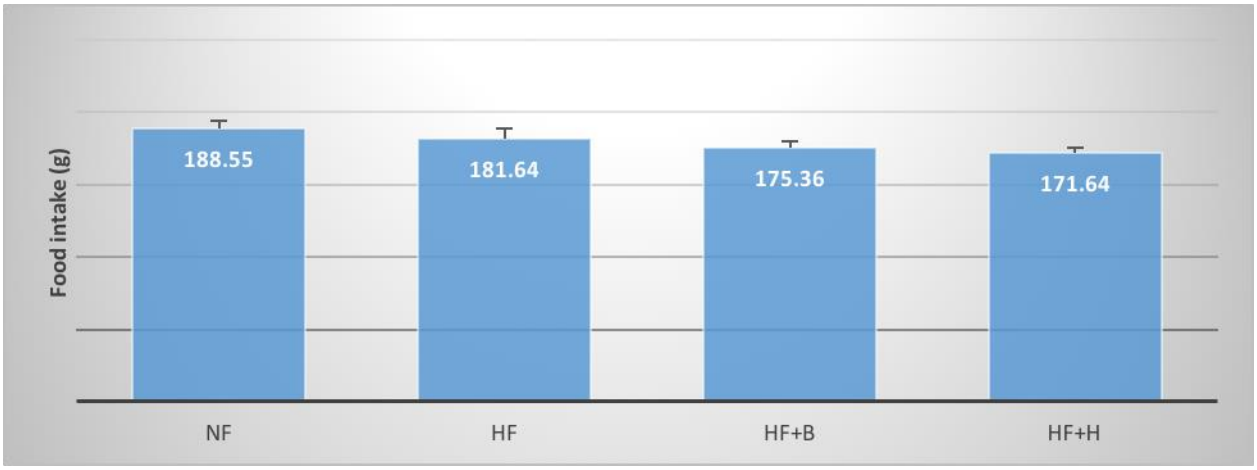

Figure 1 shows that each group consumed the same amount of food ($p > 0.05$), demonstrating that each diet was palatable. NF: No Fat Diet, HF: High Fat Diet (athero), HF + B: High Fat Diet (athero) + 5% whole beans. HF + H: High Fat Diet (athero) + 0.5% hulls. Means within columns with different letter are statistical different at $p < 0.0.5$. Data is expressed as the mean +/- standard error of the mean for n=11.

Figure 2 demonstrates that the groups gained the similar amount of weight despite ($p > 0.05$), the diet consumed, albeit the hamsters on the low fat diet below those fed the athero only or athero bean supplemented diets. NF: No Fat Diet, HF: High Fat Diet (athero), HF + B: High Fat Diet (athero) + 5% whole beans. HF + H: High Fat Diet (athero) + 0.5% hulls. Means within columns with different letter are statistical different at $p < 0.0.5$. Data is expressed as the mean +/- standard error of the mean for n=11.

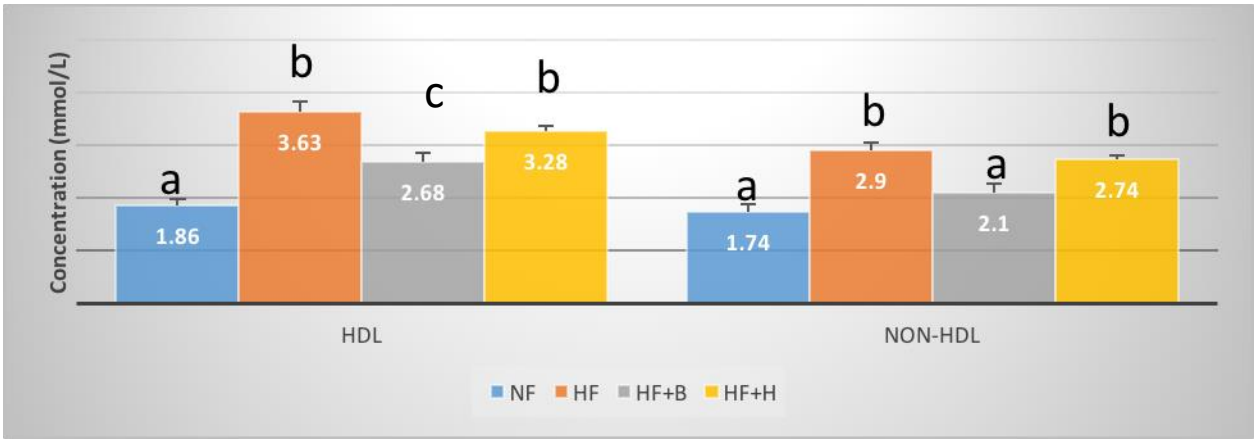

Figure 3 shows the cholesterol results from samples **collected from the plasma**. The graph demonstrates that the whole bean high fat supplemented diets (HF + B) did affect plasma non-high density lipoprotein levels (non-HDL) compared to the fatty diet only (athero) (HF), which was statistically lower than HF, but comparable to the low fat diet (NF). The hulls had no effect on non-HDL levels. For high density lipoproteins (HDL), the HF were statistically higher than the low fa diet (NF), which is typically the case, as fatty diets can result in higher levels of the good cholesterol. However, the HDL levels presented by hamsters fed the HF + B diet was slightly lower ($p < 0.05$) than the HF diet, but higher than the low fat diet. (Bars with different alphabetical letter are statistically different for each group, i.e., HDL and Non-HDL.) Means within columns with different letter are statistical different at $p < 0.0.5$. Data is expressed as the mean +/- standard error of the mean for n=11. Compared to the uncooked beans the Non-HDL response was similar, but the HDL levels were not as high for the athero + whole beans when cooked compared to the uncooked beans (data not shown). The supplemented hulls did not change HDL levels compared to animals fed HF only.

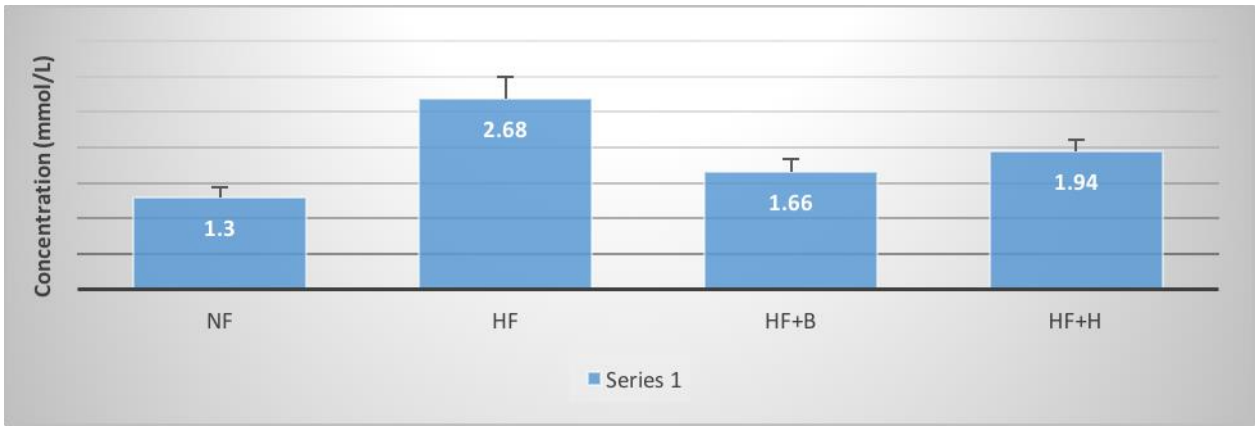

Figure 4 shows the triglyceride results from samples **collected from the plasma**. TAGs (green bars) were not affected by any of the diets. This is a positive affect for the "bad" cholesterol in response to the pinto beans $p > 0.05$. NF: No Fat Diet, HF: High Fat Diet (athero), HF + B: High Fat Diet (athero) + 5% whole beans. HF + H: High Fat Diet (athero) + 0.5% hulls. Means within columns with different letter are statistical different at $p < 0.0.5$. Data is expressed as the mean +/- standard error of the mean for n=11. Tags were similar for the cooked vs uncooked beans (data not shown.)

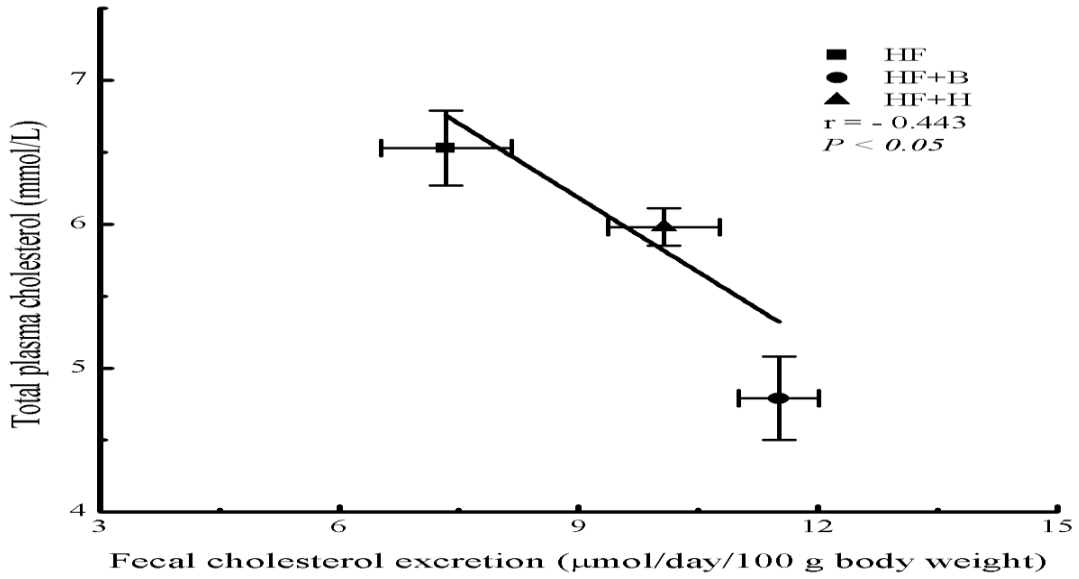

Figure 5: Total cholesterol decreased with bean intake compared to the fatty diet only (HF). This data suggest that the beans decrease non-HDL in part by excreting the cholesterol from the body. The R coefficient correlation value shows that the relationship is only moderately correlated indicating a different mechanism may be involved. A comparison with the uncooked beans showed a much higher correlation value, i.e. R = - 0.94 (data not shown), indicating that another mechanism may be involved in lowering cholesterol for both cooked and uncooked beans. Still the whole bean was responsible for producing the predominant effect. I

Table 3: Liver Cholesterol Markers

Diet group	Liver Free cholesterol (umol/g tissue)	Esterified cholesterol (umol/g tissue)	Triglycerides (umol/g tissue)
NF	3.96 ± 0.13^{b}	0.44 ± 0.14^{c}	6.38 ± 0.78^{a}
HF	4.59 ± 0.17^{a}	9.13 ± 0.30^{a}	2.85 ± 0.14^{b}
HF+B	4.15 ± 0.19^{ab}	6.10 ± 1.01^{b}	3.25 ± 0.40^{b}
HF+H	4.72 ± 0.15^{a}	9.61 ± 0.39^{a}	3.34 ± 0.53^{b}

Means within columns with different letter are statistically different at p < 0.0.5. Data is expressed as the mean +/- standard error of the mean for n=11. Esterified cholesterol was substantially high in animals fed the high fat diet (HF) diet and only shifted lower (significantly) for the whole bean supplement but this change was not as low compared to the control (NF). The free liver cholesterol and triglycerides for HF + H and HF + B were not significantly different than the fatty diet (HF) indicating minimal or no effect of the bean supplements in the liver where cholesterol is synthesized.

Table 4: Fecal sterol excretion of bile salts and neutral sterols.

Diet group	Fecal bile acids (umol/day/100g body wt)	Fecal neutral sterols (umol/day/100g body wt)
NF	1.15 ± 0.11[b]	2.19 ± 0.25[c]
HF	1.63 ± 0.17[ab]	5.71 ± 0.67[b]
HF+B	1.97 ± 0.21[a]	9.54 ± 0.57[a]
HF+H	2.21 ± 0.20[a]	7.86 ± 0.56[a]

Means within columns with different letter are statistical different at $p < 0.0.5$. Data is expressed as the mean +/- standard error of the mean for n=11. The cholesterol excreted was statically higher for the bean supplemented samples (HF +B and HF + H)

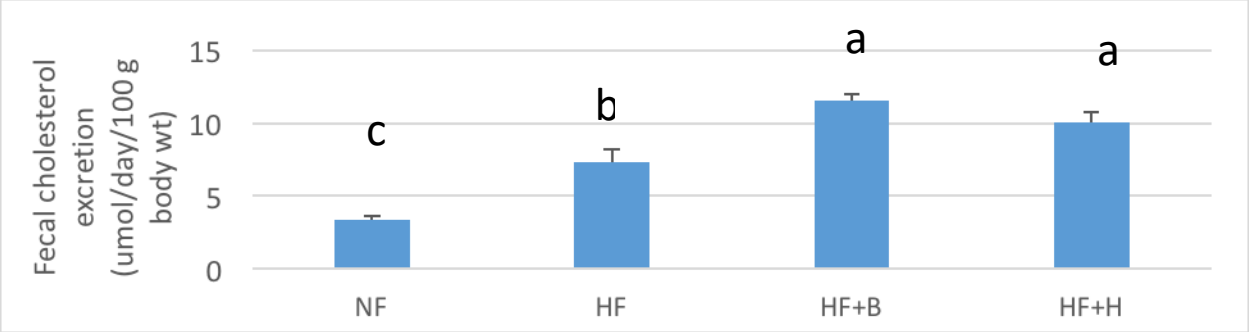

Figure 6 shows cholesterol excretion by the hamster per day, which correlates with **Table 5**. Interesting the hulls were consumed at only 10% that of the whole beans and thus had contained mush less fiber, therefore the higher micro-nutrients may have resulted in the higher excretion levels as well. Data is expressed as the mean +/- standard error of the mean for n=11. Means within columns with different letter are statistical different at $p < 0.0.5$. However, correlation of the total cholesterol present in the liver with that secreted did not show any correlation (Figure 6). These results differ with the uncooked beans as the liver total cholesterol was high correlated with fecal cholesterol excretion (-.0.94 with the high amounts of bean supplement diets resulting in the high levels of excretion, which again indicates a different mechanism occurring with the cooked beans. This data indicates that hull supplemented data excreted cholesterol similar to the whole bean, but also cholesterol was not sufficiently removed from the liver (Table 4). Still the whole bean supplement resulted in significantly reduced cholesterol from the liver into the fecal material.

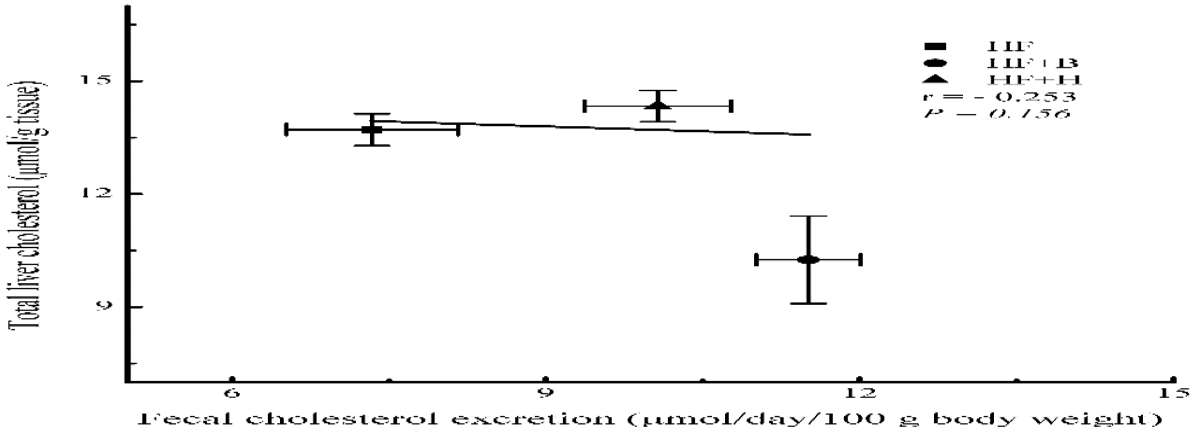

Figure 7: Total cholesterol vs cholesterol excretion. Intestinal stress (inflammation) remediation by uncooked pinto beans caused by a high fat diet. The intestine is in the process of being tested for metabolomic targeted analysis of central carbohydrate metabolism. Therefore, intermediates of glycolysis, the tricyclic acid cycle, and amino acids will be monitored. After euthanasian, the large intestine was excised from each hamster and frozen quickly in liquid nitrogen and stored in a -80 ^{o}C freezer until analysis. Metabolites (shown in Table 6) were extracted using a method developed in our lab.

Table 5: Targeted metabolites in profiling approaches

	Metabolites	Analytical method
Glycolysis intermediates	Glucose-6-phosphate	HPLC -MS
	Fructose-6-phosphate	HPLC-MS
	Fructose-1,6-bisphosphate	HPLC-MS
	Dihydroxyacetone phosphate	HPLC -MS
	3-phosphglycerate	HPLC-MS
	Phosphenolpyruvate	CE
	Pyruvate	CE
TCAcycle intermediates	Acetyl CoA	CE
	Citrate	CE
	α-ketoglutarate	CE
	Succinate	CE
	Fumarate	CE
	Malate	CE
Coenzymes	β-Nicotinamide adenine dinucleotide (NAD^+)	CE
	β-Nicotinamide adenine dinucleotide phosphate ($NADP^+$)	CE
	β-Nicotinamide adenine dinucleotide phosphate reduced (NADPH)	CE
	Flavin adenine dinucleotide (FAD)	CE
	Coenzyme A	CE
Organic acids	Oxalate	CE
	Formate	CE
	Malonate	CE
	Acetate	CE
	Lactate	CE
	Propionate	CE
	Butyrate	CE
Amino acids	L-Cysteine	GC
	L-Aspartic acid	GC
	L-Glutamic acid	GC
	L-Alanine	GC
	L-Serine	GC
	L-Threonine	GC
	trans-4-Hydroxy-L-proline	GC
	L-Valine	GC
	L-Methionine	GC
	L-Glutamine	GC
	L-Isoleucine	GC

	L-Leucine	GC
	L-Histidine	GC
	L-Phenylalanine	GC
	L-Tryptophan	GC
	Citruline	
	L-Lysine	GC
	L-Glycine	GC
	L-Proline	GC
	L-Asparagine	GC
Peptides	Glutathione (reduced form)	CE
	Glutathione (oxidized form)	CE
Nucleotide phosphates	Adenosine 5'-monophosphate (AMP)	CE
	Adenosine 5'-diphosphate (ADP)	CE
	Adenosine 5'-triphosphate (ATP)	CE
	Guanosine-5'-monophosphate (GMP)	CE
	Guanosine-5'-diphosphate (GDP)	CE
	Guanosine-5'-triphosphate (GTP)	CE
	Cytidine 5'-monophosphate (CMP)	CE
	Cytidine 5'-diphosphate (CDP)	CE
	Cytidine 5'-triphosphate (CTP)	CE
	Uridine 5'-monophosphate (UMP)	CE
	Uridine 5'-diphosphate (UDP)	CE
	Uridine 5'-triphosphate (UTP)	CE

CE – Capillary Electrophoresis, GC- Gas Chromatography, HPLC-MS-High performance liquid chromatography-mass spectrometry.

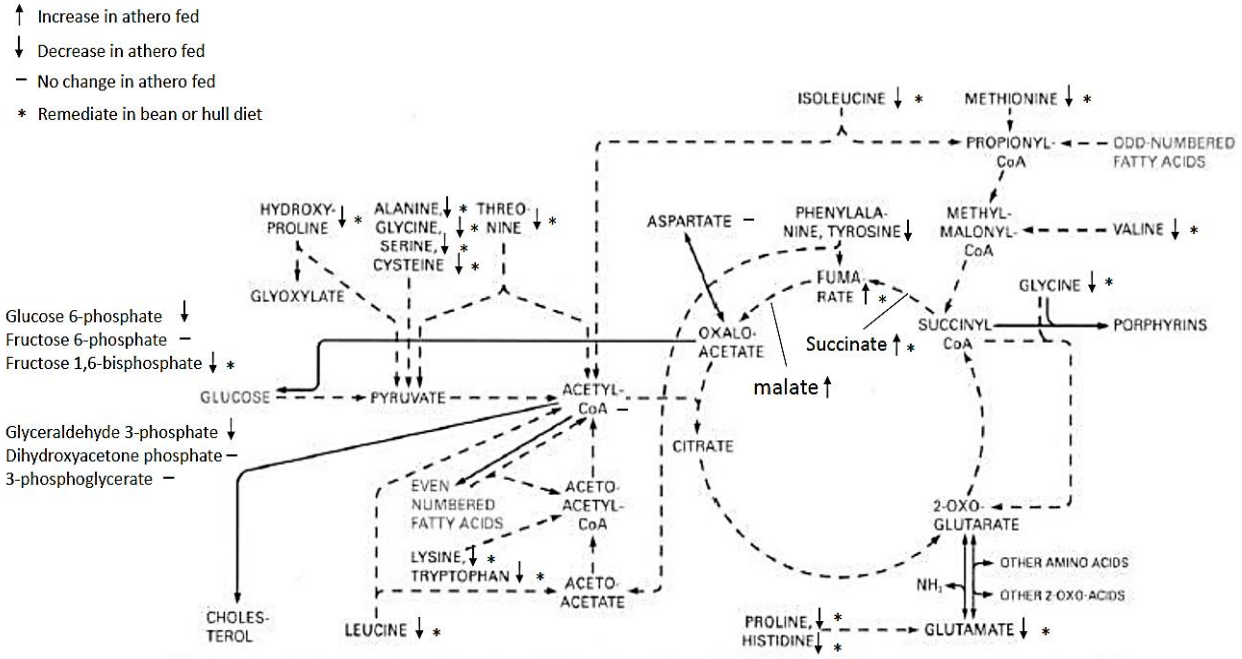

Figure 8: Pathways in energy metabolites and the various metabolites measured in the intestinal tract of the NF, HF, HF + B, and HF + H.

Project Title

Demonstration/Education: Whole Farm Integrated Vegetable Seed Production as a Specialty Crop

Project Summary

Organic or Biodynamic® U.S. vegetable seed production is a high value specialty crop with growth potential that existing farmers are not able to meet. The limiting factors include lack of farmer knowledge and skills, lack of access to appropriate sized seed processing supplies and facilities, and the necessity of isolation from cross-pollination. Therefore, this project is designed to provide small and medium sized growers with seasonal specific information required for organic and Biodynamic® seed production through on-farm field days, conference presentations, consultation, and special events. Education, training, mentorship, consultation and help in acquiring and fulfilling seed growing contracts, and access to specialized seed processing equipment are the major objectives of this project. The goal is to increase the number of successful organic seed growers in Nebraska to meet the unfulfilled and growing demand for organic seed. Below are activities that have been accomplished thus far.

Project Approach

Nathan Clark, Project Coordinator, Farmer at Meadowlark Hearth Farm, and Seedsman for Meadowlark Hearth Seeds coordinated and directed all aspects of this project, with a great deal of voluntary help from his partner, Beth Everett, and many others. The activities performed for this project included the following:

Thirteen practical on-farm workshops in seed growing, processing and handling, with use and demonstration of equipment, tools, and techniques. These included over 100 participants, many of whom went on to grow and produce seed, both for their own use, for distribution to others, or as contractors for organic seed companies. Several of these people have started or joined seed projects or seed companies to continue their work and interest in this field.

Four workshop presentations on seed growing techniques and contract production at state, regional, and national conferences. In addition, these conferences also included seed related round table discussions and breakout sessions, et cetera that were fully participated in. They also provided the opportunity to reach out to other seed growers, projects and companies to further the effectiveness of this project. Approximately 120 people participated in the conference workshops, and many more were reached through roundtables, breakout events and personal contacts.

Mentoring of 12 individuals in seed production and handling and contract fulfillment. All of these individuals have continued or begun work in seed production using the knowledge, skills and market access gained through this mentoring. Many of them have begun seed initiatives or joined existing seed projects or seed companies to further their interest and work in this field.

Acquisition and modification of specialty seed equipment available to growers and contractors of organic seed. A wet vegetable seed threshers was purchased, and a small Allis Chalmers All-Crop combine was rebuilt and modified as a stationary thresher. Seed workshops included use and demonstration of this equipment and it is now available for the use of both participants and others doing organic seed production.

Goals and Outcomes Achieved

The overall goal of this project was to increase the number of farmers who can integrate seed-saving into their farming operations. The project has achieved its goals. Total course attendance was well above the target with a cumulative attendance of approximately 225 people in on-farm and conference workshops. Quite a number of individual participants attended several of the courses and workshops due to their keen interest. The target of directly mentoring 8 farmers in the skills needed to pursue a seed growing contract to grow vegetable seeds as a specialty crop was also exceeded with 12 growers mentored in seed production.

A small scale contract seed growing seminar was provided at the Nebraska Sustainable Agriculture Society's Health Farms Conference, which was held January 29 – 20, 2016, at the Lied Lodge and Conference Center in Nebraska City, Nebraska. The title of the presentation was, "Small Scale Contract Seed Growing: Integrating seed growing into a diversified organic farm and intensive vegetable production. This class was attended by 26 people. There was a lot of energy and enthusiasm. Besides the verbal presentation, we did some hands on demonstrations of small scale seed processing. Those that filled out the evaluation questionnaire were very positive on the topics of knowledge learned. A question on the evaluation asked if the class encouraged or inspired them to become a contract seed grower. Responses were very positive as they ranged from "Absolutely!" to "Very Interested", to "Yes" to "Lots to Think About", to "Investigate Further". Seed growing also came up in the round table discussions and breakout sessions. Many contacts were made and plans for an on-farm workshop at Common Good Farm in Raymond Nebraska were made. This was held on August 6, 2016 (See below). It also led to an on-farm consultation the next day (January 31st) at Roberts Seed in Axtell, Nebraska. Overall, it was a very successful education and outreach event.

Three Biennial Seed Stock and Garden Planning Workshops were held April 8 – 10, 2016, April 22 – 23, 2017, and April 7 – 8, 2018 at Meadowlark Hearth Farm near Scottsbluff, Nebraska. Many of our annual vegetable crops are actually biennial seed producers. Cabbage, beets, carrots and onions are some examples. In the cold winter climate of Nebraska's winters, the seed plant stock for most biennials must be protected during the winter months. Mostly, this is done by lifting the plants, storing them in cool storage (a root cellar or a cool greenhouse), then replanting them outside in the spring. This is usually our first field planting in early spring, hence, the scheduled date of the workshop. In this workshop, we discussed and saw all of these techniques. We replanted the biennial stock from several different crops for seed contract production. Selection of seed stock, population and isolation requirements, the danger of crossing with naturalized wild populations, planning and integration of seed stock into the vegetable operation, protection from early freezes, hail, wind, trellis systems, management of the crop, and timing were all covered in detail. There were 12 participants, all of whom received solid, hands on experience of this important aspect of seed production. From the classroom to the field, the discussion covered all aspects of growing biennial seed crops. Participation among the group was lively and enthusiastic.

Blooming Tours and Classes were held July 9 – 10, 2016, at July 16, 2017, and July 8, 2018 at Meadowlark Hearth Farm in Scottsbluff, Nebraska. The purpose of these workshops was too see the seed plants in their reproductive stages, observe the staking and tying of plants to trellis systems, and determine the spacing, isolation and layout of a field or garden. We observed and talked about flower structure, reproductive biology, pollination vectors, pollinators, beneficial insects, hail and wind protection, stages of maturity, and when and how to harvest. There were a total of 29 participants many questions and discussions on the topics. There is nothing like being in the field and seeing it happen to give producers the sense and experience of how it is to integrate seed growing into their operations.

A Seed Saving Workshop at Common Good Farm was held August 6, 2016, near Raymond Nebraska. The purpose of this workshop was to demonstrate and explain a variety of seed saving techniques, present information on the importance of saving seed, and guide participants through selection when saving vegetable seed. This workshop was conducted after the Nebraska Sustainable Agriculture Society's Healthy Farms Conference in response to the many people from the Lincoln and Omaha area who expressed interest in exploring and learning further about contract seed growing. It started with a presentation on the techniques, challenges and processes of seed production. A lively and extensive question and answer period followed. Next, was a tour of the seed crops at Common Good Farm with discussion and observation of the biology processes and techniques of seed crop production. Tomatoes were harvested for a demonstration of the initial wet seed processing step. We brought small supplies and harvested seed plants to demonstrate threshing, winnowing, and various seed cleaning techniques. Also we brought a batch of tomato seed in the final stage of the fermentation process to demonstrate and talk about wet seed processing. There were 11 workshop participants, all of whom were lively, interested, and engaged throughout the workshop.

Labor Day Weekend Seed Festivals were held September 2 – 4, 2016, September 3 – 4, 2017, and September 1 – 3 2018 at Meadowlark Hearth Farm near Scottsbluff, Nebraska. Multiple workshops were provided discussing the ins and outs of growing seed. Tours of the seed crops and observations and discussions of the crops and techniques used were addressed. Lively, hands-on participation in threshing, winnowing, cleaning of seed lots was also addressed. A total of 25 people attended these events.

Courses in Seed Production for Professional Farmers was held October 1 – 2, 2016, October 7 – 8, 2017, and September 1 – 3, 2018 at Meadowlark Hearth Farm, Scottsbluff, NE. This course was designed for experienced growers and farmers. It focused on seed production techniques, learning how to initiate and carry out seed contracts, and figuring out how to integrate seed production into a diversified working farm.18 people attended for the two days. All of the equipment and methods for vegetable seed processing were demonstrated and used by all participants. Selection was done for seed stock in cabbages, carrots and onions. The details of planning, negotiating and fulfilling seed contracts were discussed. How to produce a high quality product by meticulous attention at every step of seed production was thoroughly gone through and discussed. There was lots hands-on experience in harvesting, processing, and handling of seed.

Conference Participation and Presentation at the Biodynamic Farming and Gardening Association's 2016 Conference was held November 19, 2016 in Santa Fe, NM. Project Director, Nathan Clark, led the workshop Growing and Selling Biodynamic Seed. In this workshop Nathan shared his 30 years of experience, with suggestions about how to begin seed growing on your farm or to further your expertise. He discussed the role of seed in the farm organism, the cultural benefits of growing seed, integrating seed growing into market and CSA production, growing seed for your farm, and growing seed to sell. Practical considerations such as plant families, populations, pollination, and isolation were addressed, as well as finding markets and how to become a sought-after grower for seed companies. A total of 27 participants attended this workshop, with a lively question and answer &A period and discussion afterwards. This event also provided outreach and recruitment through meetings and discussions with participants and exploring possible contracts and alliances with other seed distributors, growers and breeders represented or participating. A special breakout meeting around seed growing and seed breeding was held, with good participation from several growers and breeders.

Nathan Clark, the Project Coordinator, was asked and accepted a request from conference organizer to speak at the NOFA Seed Conference, Jan. 20 – 22, 2017, in Saratoga ,NY. The workshop on Biennial Seed Production had 31 participants and was held together with Tom Stearns and Jodi Lew-Smith of High Mowing Organic Seed. Many other seed companies with their directors and staff were there,

Fedco Seeds, Johnny's Selected Seeds, Fruition Seeds, Southern Exposure Seed Exchange, to name a few, as well as numerous seed initiatives, seed libraries, and seed saving groups. Nathan Clark, the Program Coordinator, participated in several panel discussions and group events, as well as the featured workshop on biennials. The conference provides outreach and recruitment through meetings and discussions with participants and exploring contracts and alliances with other participating seed producers and seed distributors.

A Field Day and Workshop in Biennial Seed Stock & Garden Planning was held April 22 – 23, 2016 at Meadowlark Hearth in Scottsbluff, NE. A hands-on intensive focused on care and rearing of biennial seed crops; carrots, brassicas, beets, etc. Topics and activities included: The main plant families in garden crops, Selection, population, isolation of biennials, the 2 year cycle of a biennial, attention through the season of the biennials: tying up plants, identifying weeds that can be a problem for seed growing in particular crops with crossing or seed cleaning, meticulousness through the whole seed process of planting, cultivation, harvest, processing, storage and distribution, and integration of seed growing into the market vegetable garden. There were 8 participants. All got solid hands on experience of this important aspect of seed production as well as class room and in the field discussion of all aspects of growing biennial seed crops. Participation was lively and enthusiastic.

Roberts Seed Farm was visited on January 31, 2016. The possibility and potential of including specialty crop vegetable seed production in the Roberts Seed operation and possible seed contracts were discussed, with a look at the facilities and supplies available for this. Altogether, two hours were spent in this activity. More work will continue to keep this as an ongoing part of the project.

Workshop and Presentation: *Growing Strong Seed the Biodynamic Way,* at the Organic Seed Alliance Conference in Corvallis, OR, February 14 – 17, 2018. Biodynamic practices help plants develop in a healthy and balanced way, access the full spectrum of nutrients they need, and become more resilient to pests, diseases, and extreme climate conditions. Demand for Demeter certified Biodynamic seed is growing among both seed companies and farmers, due to the unique quality and vitality of Biodynamic seeds. Learn how to incorporate biodynamics into your farm operations, specific biodynamic practices that can nurture and enhance the seeds that you grow, what is needed to become certified Biodynamic, and where market opportunities are emerging. In addition, participating in this conference provided outreach and recruitment through meetings and discussions with participants and exploring possible contracts and alliances with other seed distributors represented or participating.

On farm and phone consultation happened with eleven growers, most of them involving more extensive mentoring and seed contract fulfillment. Below is a description of each grower.

Toby Schweitzer of The Good Life Farm is located near Central City, Nebraska. There were four phone consultations with Toby. This farming operation had already began some contract growing for High Mowing Organic Seed Company. During the consultations, discussion centered around their particular growing situation, guidelines and challenges with his current seed crops, various potential contract seed crops, and possible contracts, potential markets, and isolation, harvesting, and processing techniques and supplies. The farm expressed interest in visiting to learn from our operation.

Clint Freund from Scottsbluff County, Nebraska participated in all of the 2016 workshops, except for the Nebraska Sustainable Agriculture Society's Healthy Farms Conference in Nebraska City. In 2016 he took on seed contracts with AP Whaley Seed Company and Southern Exposure Seed Exchange. He also grew out twelve different seed crops for Meadowlark Hearth Farm. He received guidance, mentoring, and training from the project. In 2017 he relocated and grew several seed crops for A.P. Whaley Seeds and Southern Exposure Seed Exchange expanding contracts with more seed companies and establishing a small-scaled regional seed saving operation titled "Cultivating the

Commons." He helped select and took biennial seed stock with him when he moved and is marketing cabbage seed from this, as well as some other seed crops to Nature and Nurture Seeds.

Kassie McKinnon from Banner County, Nebraska attended all of the 2016 workshops held in the Nebraska Panhandle. She expressed interest in growing a seed crop, so Meadowlark Hearth Farm gave her their seed plant stock for Dottenfelder Cabbage, which she grew out in an isolation plot on her farm in Banner County. The project provided her with training, guidance and mentoring throughout. . She came to Meadowlark Hearth Farm for an intensive 6 week practicum in seed germination testing in late 2016 and through 2017 working with Clint Freund in seed production, testing and handling.

Terry Troxel of Iowana Farm in Crescent IA, just outside of Omaha, NE, attended our April 2016 workshop and then again our fall workshop for professional growers. She contacted us for help with greenhouse tomato seed production and contracting with a seed company. There were three phone consultation and a farm visit, and she has successfully contracted with High Mowing Organic Seed for two tomato varieties in 2017. She continues to contact us for consultation and mentoring.

Emily Ambrose came to Meadowlark Hearth farm for a practicum year before completing her last year at Cornell University's School of Agriculture. She received intense on-farm training in seed production and participated in all workshops in 2016. She finished her Ag degree at Cornell in the spring of 2017, participated in the workshops we presented at the NOFA Seed Conference and worked together with Clint Freund and Kassie McKinnon in seed production, processing, marketing, and handling. She now works with Equal Exchange.

Daphne Kingsley of Light Root Farm in Boulder Colorado grew the second year biennial stock to seed for Rodynda Red Storage Cabbage in an isolation at her farm. We delivered the seed stock to Light Root Farm and gave her further consultation by email in how to do this. She will work with contract growing for Meadowlark Hearth in2019.

Steven Adams of Chrysalis Farm in Viroqua Wisconsin grew Beet Seed for three different seed companies and contacted us for phone consultation on growing, harvesting, handling and cleaning the seed, as well as how to process it to bring up the germination percentage.

Jason Griffith of Aspen Moon Farm in Hygeine, Colorado, contracted to grow the second year biennial stock of Haldor Leeks to seed at his farm. We delivered the seed stock to Light Root Farm and gave him consultation on the farm in how to do this.

Evrett Lundquist of Common Good Farm in Raymond, NE hosted a seed saving workshop presented by us and contracted to grow three vegetable seed crops, a tomato, a beet, and okra. The harvesting and processing of these were included as activities in the workshop.

Cyndi Pointe participated in four of the workshops and in addition spent several days working with us with seed harvest and processing at Meadowlark hearth Farm. She now does extensive seed saving at Raphael Garden in Fair Oaks, CA and grows contract seed for Turtle Tree Seed and Meadowlark Hearth Seeds, as well as extensive seed saving for her own operation.

Nate Kleinman and Dusty Hinz founded the Experimental Farm Network that coordinates efforts in innovative plant breeding and new crop introduction. They have a network of seed growers and breeders with whom they help to disperse and distribute unique seed and seed stock. Nate and Dusty spent two days training and helping in seed cleaning and handling at Meadowlark Hearth Farm.

Beneficiaries

We are confident that this project stimulated ongoing interest, activity, and resources that will increase these numbers over time. Meadowlark Hearth Living Environment Foundation will continue to house and make seed cleaning equipment available and sponsor training, workshops and conference events in organic and biodynamic seed saving and seed production. On November 14th, 2018 the Project Coordinator and his partner will be holding an all-day session on developing the biodynamic and organic seed supply for North America at the North American Biodynamic Conference in Portland Oregon, and in January of 2019 conference workshops at the Future Farmers of Iowa conference and at Threefold Farm in Spring Valley, NY. In addition we will continue to mentor and advise organic and biodynamic growers in seed saving and contract seed growing.

The Nebraska Sustainable Agriculture Society, the Organic Seed Alliance, the Biodynamic Association, and the North East Organic Farmers Association have all hosted or requested participation in their conferences through this grant to educate, train and engage conference participants

Lessons Learned

We were unable to attend and take part in the Organicology 2017 Conference, February 2 – 4, 2017 in Portland, Oregon due to unforeseen circumstances. A minor change was made in the budget. Some of the contractual funds for mechanical work were not needed used because much of the work was done in house instead of by a contractor. The budget was modified to move the unneeded funds to the personnel who worked on the combine and to supporting more workshops and activities.

There is a growing market for organic seed and a widespread interest among organic and biodynamic growers in seed saving and producing seed crops. This interest tends to focus in areas where organic vegetable production has become well established, particularly with growers doing CSA and direct marketing. This is not as yet very well established in Western Nebraska and we found the majority of participants and the requests for training came from a considerable distance, with a significant portion coming from out of state. For the present, this is limiting in sharing the equipment acquired through the grant. Much of it will have to be done through seed being shipped or hauled to the site where the equipment is housed, and we will have to establish how we accommodate the needs and provide the labor when the growers using the equipment need help and accommodation or cannot come to do it because of the distance. We are confident that these challenges can and will be met and that local interest and involvement will grow over time.

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